NEW ENGLAND WATER WORKS ASSOCIATION.

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REPORT ON THE MEASUREMENT, CONSUMPTION AND WASTE OF WATER SUPPLIED TO THE METROPOLITAN WATER DISTRICT.

BY DEXTER BRACKETT, ENGINEER OF THE DISTRIBUTION DEPARTMENT, METROPOLITAN WATER WORKS.

To the Metropolitan Water and Sewerage Board.

GENTLEMEN: — The following report contains the results of work done and investigations made under authority of chapter 391 of the Acts of the General Court for the year 1902, which authorized the construction of works for measuring the water used in each of the cities and towns in the Metropolitan Water District, and directed the Board to report the quantity supplied to each of the cities and towns, and also whether water is being unnecessarily or improperly used, and to make recommendations regarding the prevention of waste, and the manner of apportioning the annual assessment among the cities and towns.

The Metropolitan Water Works supply water to 18 cities and towns, having, on May 1, 1903, an estimated aggregate population of 897,600, and comprising a territory of 142.7 square miles in area, the greater portion of which lies within a radius of 10 miles from the State House. Topographically, the part of this territory where the greater portion of the water is used is less than 50 feet above sea level. The greater part of the area included in the several municipalities is, however, at a higher elevation, and at one point in the town of Milton it rises to elevation 640 above Boston city base. Other summits in the District are: Arlington Heights, elevation 377; Bellevue Hill, in West Roxbury, elevation 340; and Bear Hill, in Stoneham, elevation 315.

The area, population, number of service pipes, meters and mileage of pipe in use in the several cities and towns are shown by Table No. 1.

TABLE NO. 1.

CITY OR TOWN.	Area (Square Miles).	Estimated Population, May 1, 1903.	Number of Services, January, 1903.	Number of Meters, January, 1903.	Per Cent. of Services metered.	Miles of Pipe.
Boston,	38.2	597,900	89,384	4,617	5.2	723.0
Somerville,	4.2	67,600	10,710	271	2.5	82.5
Malden,	4.9	36,900	6,700	4,245	63.4	82.0
Chelsea,	2.3	35,900	6,257	113	.2	38.7
Everett,	3.4	28,000	4,670	49	1.0	42.0
Quincy,	16.5	26,300	4,850	152	3.1	83.7
Medford,	7.1	21,000	4,039	124	3.1	50.4
Melrose,	5.1	13,900	3,221	95	3.0	44.5
Revere,	5.9	12,700	2,261	28	1.2	34.5
Watertown,	4.1	10,800	1,692	1,515	89.5	30.1
Arlington,	5.2	9,700	1,700	94	5.5	34.3
Milton,	12.9	7,400	1,078	1,078	100.0	35.0
Winthrop,	1.6	7,300	1,747	9	.5	22.7
Stoneham,	6.6	6,400	1,157	19	1.7	19.9
Belmont,	4.6	4,800	621	621	100.0	17.9
Lexington,	16.0	4,100	620	4	.6	11.7
Nahant,	1.0	1,300	462	43	9.3	15.9
Swampscott,	3.1	5,100	1,055	-	-	17.2
	142.7	897,600	142,224	13,077	9.2	1,286.0

Previous to the formation of the Metropolitan Water District nearly all of these cities and towns drew their supplies from different sources, and maintained separate reservoirs and pumping stations. Since the construction of the Metropolitan Works eleven sources of supply have been abandoned, and the pumping, which was formerly done at twenty stations, is now done at five stations. All water delivered by the Sudbury and Cochituate aqueducts is delivered by gravity into Chestnut Hill Reservoir, whence it is raised by pumping machinery to different elevations supplying separate districts. The water delivered by the Weston Aqueduct, which was completed and placed in service on December 29, 1903, is discharged directly into the low-service mains without any pumping.

For the southern low-service district, comprising the lower portion of the city of Boston, excepting in Charlestown and East Boston, the pressure at the pumping station at Chestnut Hill is

maintained so as to deliver water in the city at an elevation of about 130 feet above Boston city base at all times during day and night.

For the northern low-service district, including the lower portion of the cities of Somerville, Medford, Malden, Everett, Chelsea, and for Charlestown and East Boston, water is pumped into Spot Pond at elevation 163 above Boston city base.

For the southern high-service district, comprising Quincy, Watertown and Belmont, and the higher portion of the city of Boston, water is pumped from Chestnut Hill to the Fisher Hill and Waban Hill reservoirs. High-water mark in the Fisher Hill Reservoir is at elevation 251, and in Waban Hill Reservoir 264.5 feet above Boston city base.

For the northern high-service district, comprising the city of Melrose, the towns of Revere, Winthrop, Nahant, Swampscott and Stoneham and the higher portions of the cities of Somerville, Medford, Malden, Everett and Chelsea, water is pumped from Spot Pond to the Fells Reservoir at elevation 271, and to Bear Hill Reservoir at elevation 300. The town of Stoneham alone is supplied from the Bear Hill Reservoir.

For the town of Lexington and the higher portion of the town of Arlington, water is pumped from the low-service mains in Arlington to a standpipe on Arlington Heights at elevation 443. For the higher portion of the town of Milton and of the West Roxbury district of Boston, water is pumped to a standpipe on Mt. Bellevue, in West Roxbury, at elevation 376.

For the year 1902 the percentage of the total consumption used in the several districts was as follows: —

Southern low-service district,	40.0
Northern low-service district,	25.0
Southern high-service district,	27.0
Northern high-service district,	7.4
Northern extra high-service district,	.3
Southern extra high-service district,	.3

Table No. 2 shows the revenue received from water rates for the year 1902 in the several cities and towns supplied by the Metropolitan Works.

TABLE NO. 2.

CITY OR TOWN.	REVENUE FROM WATER RATES.			Revenue from Metered Water.	Per Cent. of Revenue from Metered Water.
	Received from Private Consumers.	Received from Municipalities.	Total.		
Boston,	$2,306,191 98	*-	$2,306,191 98	$1,005,312 26	43.6
Somerville,	213,965 51	*-	213,965 51	50,733 53	23.7
Chelsea,	100,468 03	$6,821 00	107,289 03	23,629 86	22.0
Malden,	95,968 95	1,143 29	97,112 24	68,403 08	70.5
Everett,	80,827 74	674 40	81,502 14	23,284 50	28.6
Quincy,	78,093 48	*-	78,093 48	14,452 65	18.5
Medford,	53,549 53	6,148 72	59,698 25	6,667 48	11.2
Melrose,	49,990 22	*-	49,990 22	3,041 54	6.1
Revere,	† 32,382 93	5,117 07	† 37,500 00	1,511 95	4.0
Watertown,	31,196 88	*-	31,196 88	30,034 88	96.3
Arlington,	35,721 89	*-	35,721 89	4,065 98	11.4
Milton,	27,694 68	11,155 70	38,850 38	38,850 38	100.0
Winthrop,	† 27,818 08	4,681 92	† 32,500 00	293 71	.9
Stoneham,	19,246 35	2,400 00	21,646 35	2,123 95	9.8
Belmont,	11,840 51	452 51	12,293 02	12,293 02	100.0
Lexington,	9,729 87	4,630 99	14,360 86	736 42	5.1
Nahant,	6,382 47	800 00	7,182 47	791 96	11.0
Swampscott,	17,104 33	1,435 50	18,539 83	-	-
	$3,198,173 43	$45,461 10	$3,243,634 53	$1,286,227 15	39.7

* No revenue received for water used for municipal purposes. † Estimated.

MEASUREMENT OF WATER CONSUMED.

Before measurements and investigations could be made to determine the quantity of water used and wasted, it was necessary to provide means for measuring the water supplied to the several cities and towns. Previous to May 13, 1902, when the Act authorizing such measurement was approved, studies had been made to determine the best method of measuring the water used, and on June 20, 1902, a contract was made with the Builders Iron Foundry of Providence, R. I., for furnishing 42 Venturi meters, in sizes from 8 inches to 48 inches. These, with 3 meters previously purchased and set, and 4 meters which were subsequently ordered, make 49 meters which have been placed at the following points on the pipes supplying the several cities and towns: —

District supplied by Meter.	Location of Meter.	Size of Meter (Inches).
Arlington,	Medford Street, at Parallel Street,	20
Belmont,	Common Street, at Belmont Street,	12
Boston (2 meters),	Low-service pumping station, Chestnut Hill Reservoir,	48
Boston,	Boylston Street, Brookline,	48
Boston,	Brookline Reservoir grounds, Brookline,	30
Boston,	Chestnut Hill Reservoir, near effluent gate chamber,	48
East Boston,	Condor Street, at Brooks Street,	24
Brighton,	Chestnut Hill Avenue, at Beacon Street,	16
Charlestown,	Broadway, at Walnut Street, Somerville,	24
Charlestown,	Pearl Street, at Walnut Street, Somerville,	30
Charlestown,	Broadway, Chelsea, near North Bridge,	10
Dorchester,	Morton Street, at Blue Hill Avenue,	16
Dorchester,	River Street, at Morton Street,	12
West Roxbury,	Arborway, at South Street,	20
Chelsea,	Powder Horn Hill, at Chelsea Reservoir,	16
Chelsea,	Second Street, at Broadway,	24
Chelsea,	Second Street, Everett, at Locust Street,	12
Everett,	Broadway, at Hancock Street,	16
Everett,	Main Street, at Wyllis Avenue,	12
Everett,	Broadway, at Corey Street,	20
Lexington,	Massachusetts Avenue, at Arlington-Lexington line,	12
Malden,	Highland Avenue, at Clifton Street,	16
Malden,	Hancock Street, at Cross Street,	12
Malden,	Washington Street, at Winter Street,	16
Malden,	Clifton Street, at Washington Street,	16
Malden,	Medford Street, at Pearl Street,	12
Malden,	Medford Street, at Green Street,	16
Medford,	Governors Avenue, at High Street,	10
Medford,	Boston Avenue, at College Avenue,	8
Medford,	Governors Avenue, at High Street,	20
Medford,	Jerome Street, at High Street,	10
Melrose,	Ravine Road, right of way to Melrose Reservoir,	20
Milton,	Adams Street, at Canton Avenue,	12
Nahant,	Beach Road, at Nahant-Lynn line,	8
Quincy,	Adams Street, at Beale Street,	24
Revere,	Prospect Avenue, at Revere Reservoir,	12
Somerville,	Boston Avenue, at Professors Row,	12
Somerville,	Cedar Street, at Broadway,	16
Somerville,	Broadway, at Willow Avenue,	16

District supplied by Meter.	Location of Meter.	Size of Meter (Inches).
Somerville,	Medford Street, at Central Street,	12
Somerville,	Pearl Street, at Walnut Street,	16
Somerville,	Broadway, at Marshall Street,	12
Somerville,	Webster Avenue, near Newton Street,	20
Somerville,	Willow Street, at Elm Street,	16
Swampscott,	Ocean Street, at Nahant Road,	12
Stoneham,	High-service pumping station, Spot Pond,	24
Watertown,	Mount Auburn Street, near Irving Street,	16
Winthrop,	Atlantic Avenue, at Crescent Avenue,	16

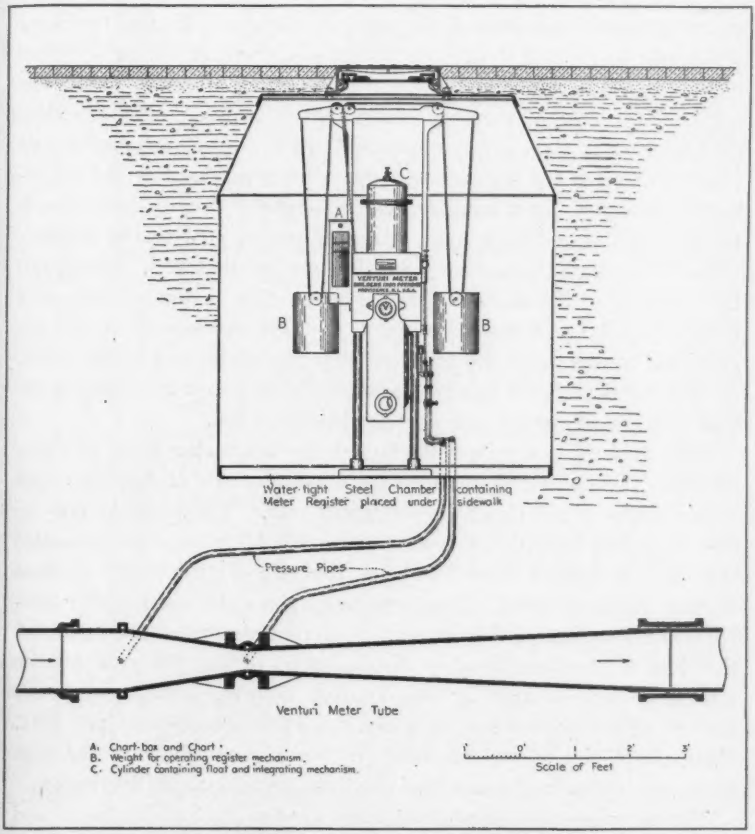
The work of setting the meters was begun in August, 1902, and continued as fast as the meters were received, until the middle of December, 1902, when the work was stopped by cold weather. It was resumed in March, 1903, and continued until June 27, when all meters required for measuring the water used in the 18 cities and towns supplied by the Metropolitan Works had been set. The cost of the work to date has been $74,088.54. This amount does not include the cost of 2 48-inch, 1 36-inch, 1 24-inch and 2 16-inch meters purchased and set previous to the passage of the Act.

Although 24 of the meter tubes were set during the year 1902, the manufacturers did not deliver any of the registering apparatus until early in 1903; and it was not until January 24 that any of the meters purchased in 1902 were placed in service.

Continuous measurements of the consumption in the several cities and towns have been made since the following dates: —

Stoneham,	January 1	Milton,	February 28
Melrose,	January 24	Chelsea,	April 11
Medford,	February 3	Quincy,	May 8
Everett,	February 6	Nahant,	June 18
Revere,	February 13	Swampscott,	June 18
Malden,	February 16	Arlington,	June 19
Watertown,	February 16	Lexington,	June 19
Belmont,	February 20	Somerville,	June 24
Winthrop,	February 26	Boston,	June 26

The Venturi meter is entirely different in principle, design and operation from the water meters in general use for measuring water used by water takers. The meter proper consists of two truncated



VENTURI METER AND REGISTER CHAMBER.

cones of cast iron, joined at the smallest diameter by a short throat piece of cast iron lined with brass, having a diameter varying in different meters from one-quarter to one-half of the diameter of the large ends of the cones, the three parts making what is known as the meter tube. At the up-stream end and at the throat small holes are drilled into the tube, from which pipes are carried to the register. The operation of the meter is due to the fact that when

water is flowing through the tube the pressure at the throat is less than at the up-stream end, and that the difference in pressure is dependent upon the quantity of water flowing through the tube. The differing pressures at the up-stream end and throat of the meter tube are transmitted through small pipes to the register, which can be located at any convenient point within 300 or 400 feet of the tube. In the register the differences of pressure affect the level of a column of mercury which carries a float. The position of this float is thus made dependent upon the quantity of water passing through the meter; and by suitable mechanism the quantity is recorded by a counter, and the rate of flow at intervals of ten minutes is recorded upon a roll of paper, so that the fluctuations in the flow throughout each day can be observed. Although the pressure at the throat of the meter is often several pounds less than at the inlet or up-stream end, the lost pressure is nearly all regained by the time the water reaches the outlet end of the tube, so that the net loss of pressure caused by the meter is seldom more than one pound, under ordinary conditions of use.

This type of meter is well adapted for measuring large volumes of water through pipes in which the maximum rate of flow does not exceed eight or ten times the minimum rate. The smallest rate of flow recorded by the 8-inch meters is 50,000 gallons per day, and the 48-inch meters record flows at the rate of 60,000,000 gallons during the same time. Comparisons of the water used in the Metropolitan District, as determined by current meter measurements of the flow in the aqueducts, by displacement of the plungers on the pumping engines and by the Venturi meters, indicate that the meters probably give results which are accurate within 2 per cent. Facsimile copies of records made by the meters, showing the rate of consumption in some of the districts, are shown on diagram 9.

The daily average quantity of water used in each of the cities and towns during each month since June 30, 1903, is given in the following table (No. 3), and in a table appended to this report will be found the daily average for each week.

TABLE NO. 3. — *Daily Average Consumption of Water in Cities and Towns supplied from Metropolitan Works as measured by Venturi Meters.*

CITY OR TOWN.	JULY.		AUGUST.		SEPTEMBER.		OCTOBER.		NOVEMBER.		DECEMBER.	
	Gallons per Day.	Gallons per Capita.	Gallons per Day.	Gallons per Capita.	Gallons per Day.	Gallons per Capita.	Gallons per Day.	Gallons per Capita.	Gallons per Day.	Gallons per Capita.	Gallons per Day.	Gallons per Capita.
Boston, . .	76,616,200	128	75,322,600	125	77,172,100	128	76,815,100	128	77,201,700	128	85,284,400	141
Somerville, .	5,944,600	88	5,357,300	79	5,630,900	83	5,424,500	79	5,267,100	77	5,863,200	85
Malden, . .	1,883,800	51	1,764,800	48	1,913,600	51	1,742,700	47	1,620,500	43	1,653,300	44
Chelsea, . .	3,330,000	93	3,195,900	89	3,190,300	88	3,194,700	88	3,218,200	89	4,150,200	115
Everett, . .	2,169,800	77	2,188,200	77	2,260,100	80	2,209,200	78	2,350,800	82	2,636,700	92
Quincy, . .	2,670,900	99	2,397,000	89	2,392,400	88	2,273,300	84	2,252,400	83	2,475,800	91
Medford, . .	1,693,200	81	1,572,800	75	1,753,600	84	1,647,500	78	1,594,000	75	1,659,400	78
Melrose, . .	1,469,300	105	1,403,500	100	1,442,800	103	1,414,600	101	1,341,300	95	1,304,600	93
Revere, . .	868,500	67	859,400	66	813,100	62	704,800	53	691,700	52	824,500	62
Watertown, .	578,100	53	549,400	50	560,400	51	525,800	48	496,600	45	480,200	44
Arlington, . .	799,700	82	640,200	65	501,900	51	554,300	56	531,300	54	567,600	57
Milton, . .	338,500	46	335,700	45	365,500	49	319,900	43	327,900	44	272,100	36
Winthrop, . .	738,300	100	758,200	102	694,100	93	602,800	80	564,500	75	640,700	84
Stoneham, . .	483,600	76	505,600	79	458,700	72	441,700	69	445,200	70	475,600	74
Swampscott, .	713,100	94	715,100	94	592,500	83	457,100	74	347,500	67	338,600	65
Belmont, . .	208,800	43	229,000	47	252,100	52	243,000	50	226,100	46	215,200	44
Lexington, . .	267,800	74	278,800	78	309,000	86	233,900	65	181,200	50	185,500	52
Nahant, . .	317,600	83	237,300	62	194,600	58	86,100	37	41,600	31	52,900	39
	101,091,800	112	98,310,800	108	100,497,700	111	98,891,000	109	98,699,600	109	109,080,500	120

The total consumption of the District, as given in the preceding table, is about $2\frac{1}{2}$ per cent. less than the consumption as measured by the displacement of the pump plungers at the pumping stations. The difference includes the quantity used in all of the pumping stations and the leakage from the Metropolitan mains and reservoirs. This use and leakage is estimated to be not less than 500,000 gallons per day.

It will be noticed that there are great differences in the per capita use in the several municipalities. To some extent these differences can be explained by the difference in the class of takers supplied; but, excepting the five larger cities, where the manufacturing and trade use is considerable, it is safe to assume that where the consumption per capita is more than 50 gallons per day the excess is wasted.

Investigations have been made to determine the amount of water used in the several municipalities for domestic purposes, for manufacturing, mechanical and trade purposes, and for public purposes; also to ascertain the various ways in which water is unnecessarily used or wasted.

Use of Water for Domestic Purposes.

The term "domestic use" will, for the purposes of this report, be understood to include not only the strictly household use, but also the water used for private stables and watering lawns. The best information regarding the quantity used for these purposes is obtained from the records of the cities and towns where all or a large percentage of the water takers are supplied through meters. Within the Metropolitan District there are about 8,500 meters supplying water for domestic purposes. In the towns of Belmont and Milton every service pipe is metered; in Watertown, 89.5 per cent.; and in Malden, 63.4 per cent.

The average daily quantity of water used for domestic purposes as measured by meters in each of these municipalities during the years 1901 and 1902 was as follows: —

CITY OR TOWN.	Number of Consumers.		Gallons per Day.		Gallons per Day per Consumer.	
	1901.	1902.	1901.	1902.	1901.	1902.
Belmont,	3,600	3,900	63,760	66,630	17.7	17.1
Malden,	21,100	22,550	414,030	450,160	19.6	20.0
Milton,	6,850	7,450	115,000	143,500	16.8	19.3
Watertown,	9,650	10,250	147,200	152,900	15.3	14.8
	41,200	44,150	739,990	813,190	18.0	18.4

The above quantities include water used for stables supplied in connection with dwellings and that used for lawn sprinkling, as well as that used strictly for household purposes. In all these municipalities the meters have been in use but a comparatively few years, and it is not probable that they have become worn so as to cause a large percentage of error in registration. The experience in other cities and towns where meters are in general use on domestic services corroborates the results obtained in the Metropolitan District.

Table No. 4 gives the per capita metered consumption for the year 1902 in several places where all or a large percentage of the water used is metered.

Table No. 4.

CITY OR TOWN.	Estimated Number of Consumers.	Per Cent. of Services metered.	Total Daily Average Metered Consumption (Gallons).	Gallons per Consumer per Day.		
				Domestic.	Manufacturing.	Totals.
Brockton,	37,300	90.0	822,670	13.2	8.5	*21.8
Fall River,	107,650	96.0	2,607,100	15.5	5.2	*22.2
Newton,	35,400	86.0	1,202,740	23.1	4.6	*34.0
Ware,	7,690	100.0	203,430	25.4	1.1	26.5
Woonsocket, R. I.,	34,474	86.7	762,280	11.6	10.5	22.1
Wellesley,	5,147	100.0	132,540	25.6	.1	25.7
Worcester,	119,330	94.5	4,331,030	16.1	17.8	*36.3
Yonkers, N. Y.,	51,000	98.7	2,413,380	19.7	22.0	*42.7
	398,491	–	12,475,270	16.7	–	–

* Includes water used for public purposes.

The statement sometimes made that the greatest use or waste of water is to be found in the cheapest class of houses is not substantiated by the results obtained where water is supplied by meter. On the contrary, experience seems to indicate that the per capita

use of water for domestic purposes increases with the value of the property supplied.

This is illustrated by the following tables (Nos. 5 and 6), the first of which gives the per capita consumption in tenement houses in the city of Boston during the year 1902, and the second the per capita consumption in houses of differing value in other cities: —

TABLE No. 5. — *Use of Water in Tenement Houses in Boston during 1902.*

WARD.	Number of Houses.	Number of Families.	Number of Persons.	GALLONS PER DAY.		Monthly Rental.
				Per Family.	Per Capita.	
Ward 6,	21	263	1,226	115	24.8	$12 to $16
Ward 7,	8	75	365	71	14.5	12 to 16
Ward 7,	13	155	755	64	13.2	16 to 20
Ward 8,	15	131	625	113	23.7	16 to 20
Ward 9,	20	171	758	92	20.7	12 to 20
Ward 8,	12	116	553	141	29.6	20 to 25
Ward 8,	10	88	420	138	29.0	25 to 30
Ward 10,	21	209	949	150	33.1	25 to 30
Ward 10,	20	250	1,135	200	43.9	30 to 40
Ward 11,	10	111	545	190	38.7	25 to 45
Ward 11,	10	89	437	194	39.5	35 to 55
Ward 11,	9	81	398	218	44.4	50 upwards
	169	1,739	8,166	139	29.63	-

TABLE No. 6. — *Domestic Consumption per Capita in Newton, Fall River, Worcester and London, Eng., as determined by Meter Measurement.*

CITY OR TOWN.	Number of Houses.	Number of Families.	Number of Persons.	CONSUMPTION (GALLONS).		Remarks.
				Per Family.	Per Capita.	
Newton,	490	490	2,450	132.5	26.5	All houses supplied with modern plumbing.
Newton,	-	619	3,005	-	6.6	These families have but one faucet each.
Newton,	-	278	1,390	34.5	6.9	These families have but one faucet each.
Fall River,	28	34	170	127.5	25.5	The most expensive houses in the city.
Fall River,	64	148	740	42.0	8.4	Average class of houses, generally having bath and water-closet.
Worcester,	-	81	327	80.2	19.9	Woodland Street, best class of houses.
Worcester,	-	37	187	118.1	23.4	Cedar Street, best class of houses.
Worcester,	-	93	447	95.0	19.8	Elm Street, houses of moderate cost.
Worcester,	-	245	1,104	55.1	12.2	Southbridge Street, cheaper houses.
Worcester,	-	229	809	55.0	15.6	Austin Street, cheaper houses.
London, Eng.,	1,169	-	8,183	-	25.5	Houses renting from $250 to $600; each have bath and two water closets.
London, Eng.,	727	-	5,089	-	18.6	Middle class, average rental, $200.

During the past thirty years the number of water fixtures has increased much faster than the population. In Boston, for example, the average number of fixtures per capita increased from .523 in 1870 to 1.165 in 1900, so that the opportunities for the use and waste of water were greatly increased. It is probable that there is likely to be still further increase in the use of water for domestic purposes, even though it be supplied and paid for by meter measurement; but it does not seem probable that the quantity needed will exceed 25 gallons per capita for many years to come.

Use of Water for Manufacturing, Mechanical and Trade Purposes.

The use of water for manufacturing, mechanical and trade purposes varies to a wide degree in different municipalities, depending upon the extent of business and trade and upon the character of the purposes for which water is used. The manufacturing and trade use in the Metropolitan Water District is centered in Boston, although the per capita use for these purposes is quite large in several other cities and towns.

The greater portion of the water used for manufacturing and trade in the Metropolitan District is supplied through meters, and the metered use in the several municipalities for these purposes during the year 1902 was as follows: —

TABLE NO. 7. — *Water supplied through Meters for Manufacturing, Mechanical and Trade Purposes, during the Year 1902.*

[Gallons per capita per day.]

	Boston.	Somerville.	Chelsea.	Malden.	Everett.	Quincy.	Medford.	Melrose.	Revere.	Watertown.	Arlington.	Milton.	Winthrop.	Stoneham.	Belmont.	Lexington.	Nahant.	Swampscott.	Metropolitan District.
Bakeries,	.07	.06	.18	–	.04	–	–	.03	–	–	–	–	–	–	–	–	–	–	.06
Breweries and bottling,	.96	.10	–	–	.04	–	–	–	–	–	–	–	–	–	–	–	–	–	.65
Electric companies,	1.73	.62	–	1.40	–	.31	–	–	1.42	–	–	–	–	–	–	.58	–	–	1.29
Elevators and motors,	1.70	.09	.04	.08	.02	–	.08	.07	.01	–	–	.04	.03	–	.03	–	–	–	1.16
Factories and machine shops,	2.10	.73	6.15	.86	.37	2.03	.48	.19	–	1.91	.09	.11	–	1.74	–	–	–	–	1.86
Farms and greenhouses,	.04	.02	–	.04	–	.02	.02	.16	.10	1.06	4.12	.01	–	.23	4.76	–	–	–	.12
Gas works,	.31	–	.05	.11	13.46	–	–	–	–	–	.23	–	–	–	–	.28	–	–	.63
Hotels,	2.70	.07	.13	.08	–	.06	.08	.16	.16	–	.18	–	–	–	–	–	–	–	1.83
Iron works,	.29	.01	.35	–	1.22	–	–	–	–	–	–	–	–	–	–	–	–	–	.25
Laundries,	.41	–	.12	.01	.05	–	.29	.08	–	–	–	.02	–	–	–	–	–	–	.29
Offices and stores,	5.12	.39	.12	.70	.23	.28	.63	.19	–	.64	.41	.07	–	–	.03	–	–	–	3.53
Oil and chemicals,	.12	.16	.06	.06	2.61	–	.68	.04	–	–	.02	–	–	–	–	–	–	–	.19
Railways,	5.62	5.63	2.62	.04	.04	–	1.08	.17	–	.66	.67	.01	–	1.17	.19	1.67	–	–	4.35
Restaurants and saloons,	.85	–	–	–	.11	–	–	–	–	–	–	–	–	–	–	–	.10	–	.57
Shipping,	.77	.10	1.25	.06	–	.10	–	–	–	–	–	–	–	–	–	–	.27	–	.57
Slaughtering,	.09	5.35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	.46
Stables,	.59	.48	1.27	.15	.19	.01	.15	.45	–	–	–	.36	–	.18	.05	–	1.21	–	.51
Sugar refineries,	1.12	–	–	–	–	2.32	–	–	–	–	–	–	–	–	–	–	–	–	.82
Miscellaneous,	.30	.11	.01	.35	.22	1.58	.45	–	.19	–	.38	4.07	.14	–	–	–	–	–	.33
Totals,	24.90	13.98	12.38	3.93	18.61	6.72	3.89	1.54	1.88	4.27	6.11	4.69	.17	3.34	5.06	2.52	1.58	–	19.47

Careful estimates of the quantity of water used for these purposes, which is not metered, indicate that the amount is not more than 5 gallons per capita in Boston and from 2 to 3 gallons per capita in other cities and towns in the District, with an average of about 4 gallons for the whole District. This quantity, added to the quantity supplied through meters, gives about 23.5 gallons per capita per day required at the present time for manufacturing, mechanical and trade purposes in the Metropolitan Water District.

In other cities of the United States there exists a wide difference in the amount of water used from the public water supplies for manufacturing and mechanical purposes, depending upon the character of the manufacturing carried on or the rates charged for water, and upon other local conditions.

The following table (No. 8) gives the total metered consumption in 1902 in several of the largest cities of the United States, where very little or none of the water supplied for domestic use is metered: —

TABLE NO. 8.

CITIES.	Number of Meters.	Daily Average Metered Consumption (Gallons).	Per Cent. of Services metered.	Gallons per Capita.	Gallons per Metered Service per Day.
Boston,	5,381	17,521,400	6.03	29.90	3,393
St. Louis, Mo.,	4,635	15,149,000	6.41	23.30	3,495
Baltimore, Md.,	2,182	13,226,000	2.17	25.20	6,061
Buffalo, N. Y.,	1,375	16,501,800	2.04	46.00	12,000
Pittsburg, Pa.,	394	4,279,000	1.09	16.40	10,860
Detroit, Mich.,	5,847	14,970,800	9.24	42.70	2,543
Chicago, Ill.,	7,075	41,096,000	2.18	18.30	5,809
Philadelphia, Pa.,	1,510	16,430,400	.59	12.20	10,881

In the city of Buffalo the water rates are very low, and the use of water for manufacturing and mechanical purposes is very large. From 2.04 per cent., or about one-fiftieth of the service pipes in use, there are drawn daily 16,501,800 gallons, — an amount equivalent to 46 gallons per inhabitant for the whole city. This per capita quantity used by a comparatively few water takers is 8 gallons more than the per capita consumption in the city of Fall River for all purposes, domestic, manufacturing and public. In Fall River the use of water from the public water supply for manufacturing and trade

purposes is only 5 gallons per capita, the factories obtaining their supply of water from a stream which flows through the city.

A comparison of the figures giving the percentage of services metered and the daily number of gallons used per meter and per capita indicates that but a small portion of the total manufacturing, mechanical and trade uses are metered in several of the cities, and that the total use for these purposes is much larger than in the Metropolitan District.

Use of Water for Public Purposes.

The principal uses included under this head are for public buildings, for public fountains, for sprinkling streets, for flushing water pipes and sewers, and for extinguishing fires.

While the quantity used for public purposes in most cities is a very small proportion of the total quantity used, there is a large difference in the quantity used in different cities, and in some instances the public use is quite a large proportion of the total. Where no charge is made for water used in public buildings and for other public uses, it often happens that little or no attention is given by the officials in charge to prevent the extravagant use or waste of water, and for this reason the quantity used is sometimes very large. In the several municipalities comprising the Metropolitan Water District the practice regarding payment for water used for public purposes is not at all uniform. In Boston, Somerville, Quincy, Melrose, Watertown, Arlington and Stoneham the water departments receive no income from water furnished to other departments of the municipality; but in Watertown, Quincy and Stoneham the income from water rents is insufficient to pay the maintenance, interest and sinking fund requirements, and a sum to meet the deficiency is raised by general taxation. In Chelsea, Revere, Milton, Winthrop, Lexington and Nahant the water departments receive an income for water used for all public purposes, including a payment for fire hydrants. In Malden, Everett and Belmont an income is received for water used in public buildings, but no charge is made for fire hydrants or for water used in sprinkling streets and flushing sewers. In Medford an income is received for water used in public buildings and for fire hydrants, but not for street sprinkling and flushing sewers.

Public Buildings.

Under the head of public buildings are included schools, fire engine houses, State House, city and town halls, hospitals, asylums and jails, churches and theatres, and all other national, State, county and municipal buildings.

The best measurement of the quantity required for public schools is that furnished by the records in several of the cities and towns where the water furnished to the schools has been metered. The results of these measurements are given in the following table (No. 9): —

TABLE NO. 9. — *Use of Water in Schools.*

CITY OR TOWN.	Year.	Number of Schools metered.	Teachers and Scholars in Schools metered.	Total Teachers and Scholars in City.	Gallons per Scholar per School Day.*	Gallons per Day per Inhabitant for Schools.	Remarks.
Boston, . .	1899	†-	72,190	72,190	6.22	.41	All metered except about 7 per cent.
Malden, . .	1901	17	5,446	5,446	2.21	.17	
Malden, . .	1902	18	5,640	5,640	2.26	.18	
Medford, . .	1901	13	2,734	3,214	4.02	.33	
Medford, . .	1902	13	2,874	3,354	4.11	.34	
Belmont, . .	1902	4	626	626	6.96	.48	
Milton, . .	1901	6	1,122	1,122	6.56	.53	One school of 70 scholars does not use city water, and is not metered.
Somerville, .	1899	22	9,004	9,228	6.29	.46	All except one school metered.

* This column is based on the assumption that there are 180 school days in the year.

† The quantity used was metered, except about 7 per cent., which was estimated from the amount received from annual rates at 14 cents per 100 cubic feet. The number of scholars in the unmetered schools could not be readily ascertained.

The use for public schools should not exceed .5 of a gallon per capita of the total population. The private schools and colleges in the Metropolitan District used by meter measurement, in the year 1902, a quantity equivalent to .2 of a gallon per capita of the entire population, which, added to the public school use, gives .7 of a gallon for the total use of schools.

During the year 1902 the water used through meters in the national, State and county buildings in the District, including the use at the Navy Yard and the Watertown Arsenal, was equivalent to .58 of a gallon per capita; and the quantity supplied through meters to the

hospitals, asylums, jails and prisons was equivalent to .5 of a gallon per capita. In Boston the water supplied to the public institutions on Deer, Long, Rainsford and Gallops islands, the city hospital, the insane asylum, city hall, fire engine houses and other municipal buildings is not metered, neither is that supplied to public buildings in several other cities and towns. This unmetered quantity is estimated at 1.5 gallons per capita of the total population.

In churches, theatres, clubs and public halls the quantity used in 1902 by meter measurement was equivalent to .4 of a gallon per capita, and it is probable that at least .1 of a gallon was used which was not metered, making the use for these purposes .5 of a gallon per capita per day.

The total for public buildings is as follows: —

	Gallons.
Schools,	.70
National, State and county buildings, metered,	.58
Hospitals, asylums and jails, metered,	.50
Churches, theatres and clubs, metered,	.40
Public buildings, other than schools, unmetered,	1.60
Total for public buildings,	3.78

Public Fountains.

The estimated quantity of water used by 139 public drinking fountains, which are located in the several cities and towns supplied by the Metropolitan Works, averages 664,640 gallons per day, equivalent to .74 of a gallon per capita of the population supplied.

The following table (No. 10) shows the estimated quantities used in the several cities and towns: —

TABLE No. 10.

City or Town.	Number of Public Drinking Fountains.	Estimated Daily Average Quantity used (Gallons).	City or Town.	Number of Public Drinking Fountains.	Estimated Daily Average Quantity used (Gallons).
Arlington,	4	10,120	Nahant,	3	9,030
Belmont,	2	11,230	Quincy,	9	34,060
Boston,	62	380,900	Revere,	4	16,040
Chelsea,	2	17,240	Somerville,	6	33,410
Everett,	3	16,670	Stoneham,	1	1,560
Lexington,	3	10,490	Swampscott,	4	11,810
Malden,	11	48,460	Watertown,	4	5,500
Medford,	10	32,280	Winthrop,	4	13,770
Melrose,	4	8,810			
Milton,	3	3,260	Total,	139	664,640

In the greater proportion of the drinking fountains the water runs continuously, and it follows that the greater part of the water is wasted. The average use in 18 fountains of this class in Boston, as determined by measurement, was 14,000 gallons per day each. Thirty-three of the drinking fountains for animals used in Boston are so arranged that during the six summer months the flow into the trough is controlled by an automatic valve, and no water is wasted; during the winter season the flow is continuous. Meters attached to two of these fountains showed that the use during the summer was at the rate of 1,250 gallons per day, and during the winter, when less water is needed, 6,250 gallons, or five times the summer use.

In the city of Boston there are 20 ornamental playing fountains, located on the Common, public gardens and public squares, nearly all of which are allowed to run continuously during six months of the year. The quantity discharged by these fountains has been measured where practicable, and the total quantity is estimated to be 237,000 gallons per day for six months, equivalent to .2 of a gallon per capita for the whole year. The combined use for drinking and ornamental fountains is about 1 gallon per capita per day.

Street Sprinkling.

For sprinkling streets throughout the Metropolitan District in the year 1901 the quantity used is estimated to have been nearly 700,000,000 gallons, equivalent to 2.13 gallons per capita per day for the year.

TABLE NO. 11. — *Water used for sprinkling Streets in the Metropolitan District, 1901.*

CITY OR TOWN.	Total Gallons.	Gallons per Square Yard of watered Street, per Year.	Gallons per Capita per Day.	Average Width (Feet).	Length of Street watered (Miles).	Basis of Estimates.
Arlington,	6,960,000	44.1	2.12	35.0	7.69	Estimated by town engineer and superintendent of streets.
Belmont,	2,250,000	18.8	1.47	30.0	6.82	Estimated by superintendent of streets.
Boston,	492,046,200	* 51.0	2.35	* 31.9	* 476.00	Record kept by cart-loads.
Chelsea,	14,198,600	42.9	1.12	27.0	18.14	Record kept by cart-loads.
Everett,	18,214,800	44.9	1.87	28.8	23.91	Estimated by superintendent of Board of Public Works.
Malden,	23,664,900	54.0	1.87	31.1	24.05	Record kept by cart-loads.
Medford,	23,795,900	51.5	3.41	28.2	27.96	Estimated from data furnished by street department.
Melrose,	10,000,000	38.8	2.06	27.0	16.22	Estimated by superintendent of Public Works.
Milton,	14,559,900	27.5	5.87	21.2	42.57	All metered at standpipes.
Nahant,	3,784,000	21.6	8.63	24.0	12.45	Estimated by superintendent of streets.
Quincy,	12,960,000	57.0	1.43	26.0	14.90	Estimated by commissioner of Public Works.
Revere,	3,942,500	19.7	.96	31.4	10.88	Record kept by cart-loads.
Somerville,	45,780,300	60.5	1.97	24.3	53.02	Estimated by street department.
Stoneham,	1,400,000	31.8	.60	37.5	2.00	Estimated by water department.
Swampscott,	6,292,800	36.7	3.67	28.4	10.26	Estimated by superintendent of Water Works.
Watertown,	13,450,000	51.6	3.67	39.3	11.33	Estimated by superintendent of streets.
Winthrop,	5,900,600	19.2	2.48	25.8	20.28	Record kept by cart-loads.
	699,200,500	48.1	2.13	30.1	778.48	

Total square yards, 13,754,700.

* Length of sprinkled roadways in Boston park system not known, and so not included with these figures. The amount of water used for this purpose was 37,500,000 gallons, and this is included in the other two columns.

The quantity used in the several municipalities has been determined from the best data obtainable. In the town of Milton the water was measured by meter at each standpipe; in Boston, Chelsea, Malden, Revere and Winthrop a record was kept of the number of loads used and the capacity of the carts; in other municipalities the quantity used has been estimated by the department officials; and, while there are doubtless inaccuracies in some of the items, it is thought that the total is fairly correct.

Flushing Water Pipes and Sewers and extinguishing Fires.

Very little information is available from which to estimate the quantity used for flushing water pipes and sewers and extinguishing fires. Although large quantities of water are at times drawn from the pipes for extinguishing fires and for flushing water pipes, the use continues for but a short time, and the total use during the year is comparatively small; the per capita yearly use probably does not exceed .20 of a gallon.

The quantity required for public purposes may be summarized as follows: —

	Gallons per Capita.
Public buildings,	3.78
Drinking and ornamental fountains,	1.00
Street sprinkling,	2.13
Flushing water pipes and sewers and extinguishing fires,	.20
	7.11

Quantity actually needed for All Purposes.

From the preceding statements the total quantity actually required for legitimate use in the Metropolitan Water District at the present time is shown to be less than 60 gallons per inhabitant per day, divided as follows: —

	Gallons.
Domestic use,	25.0
Manufacturing, mechanical and trade use,	23.5
Public use,	7.0
	55.5

Quantity of Water wasted.

If, as has been stated, the actual requirements for domestic, manufacturing, trade and public purposes in the Metropolitan District do not exceed 60 gallons per inhabitant, while the total supplied to the District is nearly 120 gallons, it is evident that one-half of the water furnished must be wasted either from the street mains and service pipes, or from the water fixtures and piping on the premises of the water takers. A strong proof of the existence of waste is shown by measurements of the water used between 1 and 4 A.M., when the legitimate use of water is at its minimum.

The following table (No. 12) gives the results of continuous measurements of the water used in each of the cities and towns sup-

plied by the Metropolitan Works for the period of six months, from June 28, 1903, to January 2, 1904, and shows not only the daily average quantity used, but also the rate of use between the hours of 1 and 4 A.M. : —

TABLE No. 12. — *Daily Average (24 Hours) and Night Rate of Consumption from Metropolitan Works, June 28, 1903, to January 2, 1904.*

CITY OR TOWN.	Service.	Estimated Population.	Average Daily Consumption (Gallons).	Average Daily per Capita (Gallons).	Average Night Rate 1 to 4 A.M. (Gallons per 24 Hours).	Night Rate per Capita (Gallons per 24 Hours).
Arlington,	High,	3,005	252,000	84	* 200,000	67
	Low,	6,840	367,000	54	* 225,000	33
	Total,	9,845	619,000	63	425,000	43
Belmont,	High,	4,875	228,000	47	111,000	23
Boston,	High,	199,750	24,763,000	124	17,259,000	86
	Low,	402,425	53,465,000	133	37,846,000	94
	Total,	602,175	78,228,000	130	55,105,000	92
Chelsea,	High,	7,480	537,000	72	352,000	47
	Low,	28,645	2,862,000	100	2,005,000	70
	Total,	36,125	3,399,000	94	2,357,000	65
Everett,	High,	7,255	370,000	51	220,000	30
	Low,	21,195	1,937,000	91	1,332,000	63
	Total,	28,450	2,307,000	81	1,552,000	55
Lexington,	High,	3,600	243,000	68	* 135,000	38
Malden,	High,	8,995	493,000	55	278,000	31
	Low,	28,320	1,271,000	45	647,000	23
	Total,	37,315	1,764,000	47	925,000	25
Medford,	High,	4,030	454,000	113	318,000	79
	Low,	17,005	1,200,000	71	680,000	40
	Total,	21,035	1,654,000	78	998,000	48
Melrose,	High,	14,015	1,395,000	100	1,000,000	71
Milton,	High,	7,475	325,000	44	115,000	15
Nahant,	High,	† 2,555	158,000	62	* 50,000	20
Quincy,	High,	27,135	2,415,000	89	1,554,000	57
Revere,	High,	13,165	796,000	60	494,000	38
Somerville,	High,	15,985	1,152,000	72	605,000	38
	Low,	52,325	4,448,000	85	2,811,000	54
	Total,	68,310	5,600,000	82	3,416,000	50
Stoneham,	High,	6,400	467,000	73	322,000	50
Swampscott,	High,	† 6,380	527,000	83	* 260,000	41
Watertown,	High,	10,950	532,000	49	217,000	20
Winthrop,	High,	7,485	668,000	89	414,000	55
District totals,	High,	350,535	35,775,000	102	23,904,000	68
	Low,	556,755	65,550,000	118	45,546,000	82
Totals,		907,290	101,325,000	112	69,450,000	77

* Estimated. † Allowance made for transient population during summer months.

It will be noticed that both the daily per capita and night rates of consumption vary widely in different districts, even where the takers are of the same general class. Where the rate for twenty-four hours is large, the night rate is in almost every case excessive. It is also noticeable that the lowest rates of consumption are to be found in those districts where water meters are in general use. Take, for example, the rates of consumption during the night in Milton, Watertown, Belmont and Malden, as compared with those in Medford, Melrose, Winthrop and the high-service districts of Brighton and Chelsea. The population of each of these groups is about 60,000. They are districts in which the manufacturing use is very small, and there appears to be no good reason why the legitimate use of water between the hours of 1 and 4 A.M. should not be very small in every case. In the first group the rate varies from 13.4 to 25.5 gallons per capita, with an average of 18 gallons; while in the second group it varies from 43 to 71.4 gallons, with an average of 58.3 gallons. The difference between 18 and 58 gallons is unquestionably preventable waste.

In districts where the use for manufacturing, mechanical and trade purposes is large, the legitimate use during the night is in some instances also large. Water is used in considerable quantities during the night, as well as the day, in electric light and power stations, gas works, hotels and large institutions. For example, at the New England Gas and Coke Works in Everett water is used between the hours of 1 and 4 A.M. at the rate of 500,000 gallons per day, which is equivalent to 18.5 gallons per capita per day for the entire population of the city. This, however, is an exceptional case. Considering the whole Metropolitan District, the legitimate draft during the night is very small, when compared with 77 gallons per capita, which was the average minimum rate during the last six months of the year 1903. Nearly all of the water used for manufacturing, mechanical and trade purposes is metered, and the total is but 23.5 gallons per capita, of which the greater part must be used during the day. It is not probable that the legitimate use for all purposes during the hours of minimum consumption is more than 17 gallons per capita, in which case the difference between 77 gallons drawn from the pipes and 17 gallons used, or 60 gallons, must be wasted. This amount agrees very closely with the amount obtained

by subtracting the total quantity estimated as actually required for all purposes in the Metropolitan District from the total quantity used.

Diagram No. 1 shows graphically the comparative volume of water used and wasted in the several municipalities, the cities and towns being arranged in order of per capita use. The unshaded areas at the top of the diagram show the estimated volume legitimately used, and the shaded areas at the bottom of the diagram the volume wasted. The dotted lines show the minimum rate of use, and the areas between the dotted lines and the shaded areas show the estimated use during the hours of minimum consumption.

Diagram No. 2 shows the rate of consumption in the whole district supplied by the Metropolitan Works for each hour during three weeks, as measured by Venturi meters. During the week ending July 11, 1903, the weather was hot and dry, especially during the latter part of the week; during the week ending August 8 the weather was comparatively cool, with showers and little sunshine; and during the week ending January 9, 1904, was extremely cold. On Monday, July 6, .42 of an inch of rain fell, making street sprinkling unnecessary until Tuesday afternoon. For this reason the use during Monday, July 6, was very nearly the same as on Monday, August 3. During the last four days of the week ending July 11 the maximum temperature was from 89 to 95 degrees, and a large amount of water was used for sprinkling streets and lawns. The consumption for these days was from 14,000,000 to 17,000,000 gallons per day more than during the corresponding days of the week ending August 8, when frequent showers and cool weather made both street and lawn sprinkling unnecessary. During both of these weeks the minimum rate of use was about 75 gallons per capita. The dotted upper line on the diagram shows the use during a week of very cold weather.

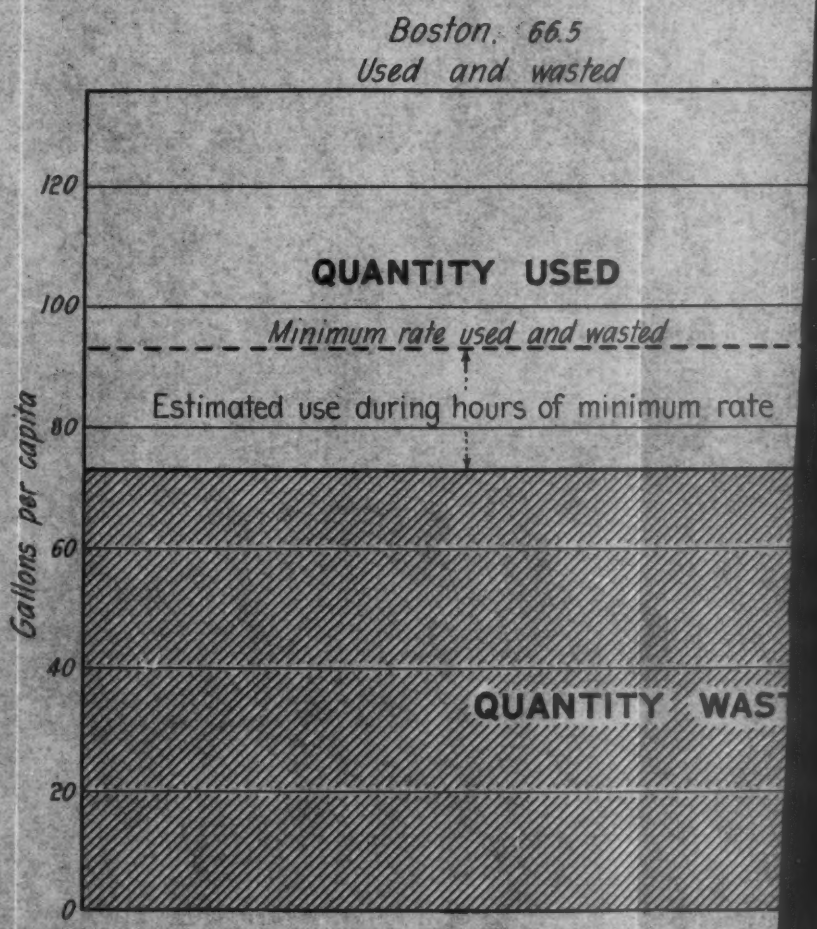
Causes of Waste.

Water is wasted, either negligently or wilfully, from mains and service pipes in the public streets, or from pipes and fixtures on the premises of the water takers.

Waste from Street Mains and Services.

The amount wasted from the street mains and service pipes is a much larger percentage of the total consumption than has been

Diagram showing the per capita quantity of wa
several cities and towns supplied by the Metr
Figures following names of cities and towns show percen



g the per capita quantity of water
nd towns supplied by the Metropo
names of cities and towns show percentage

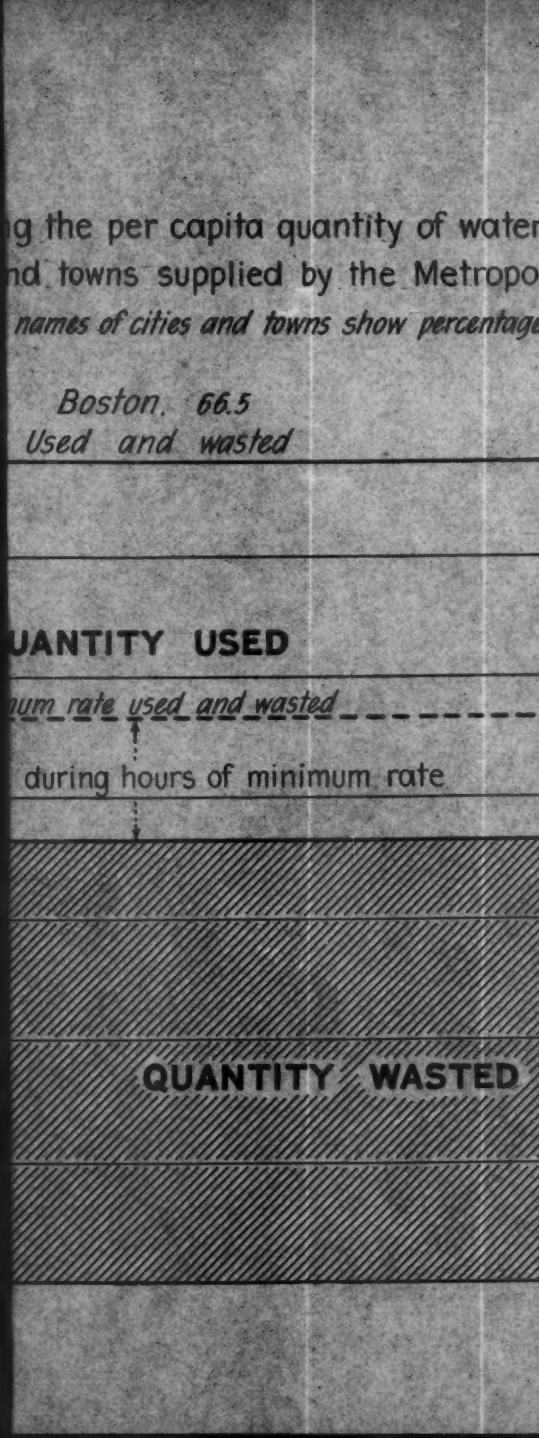
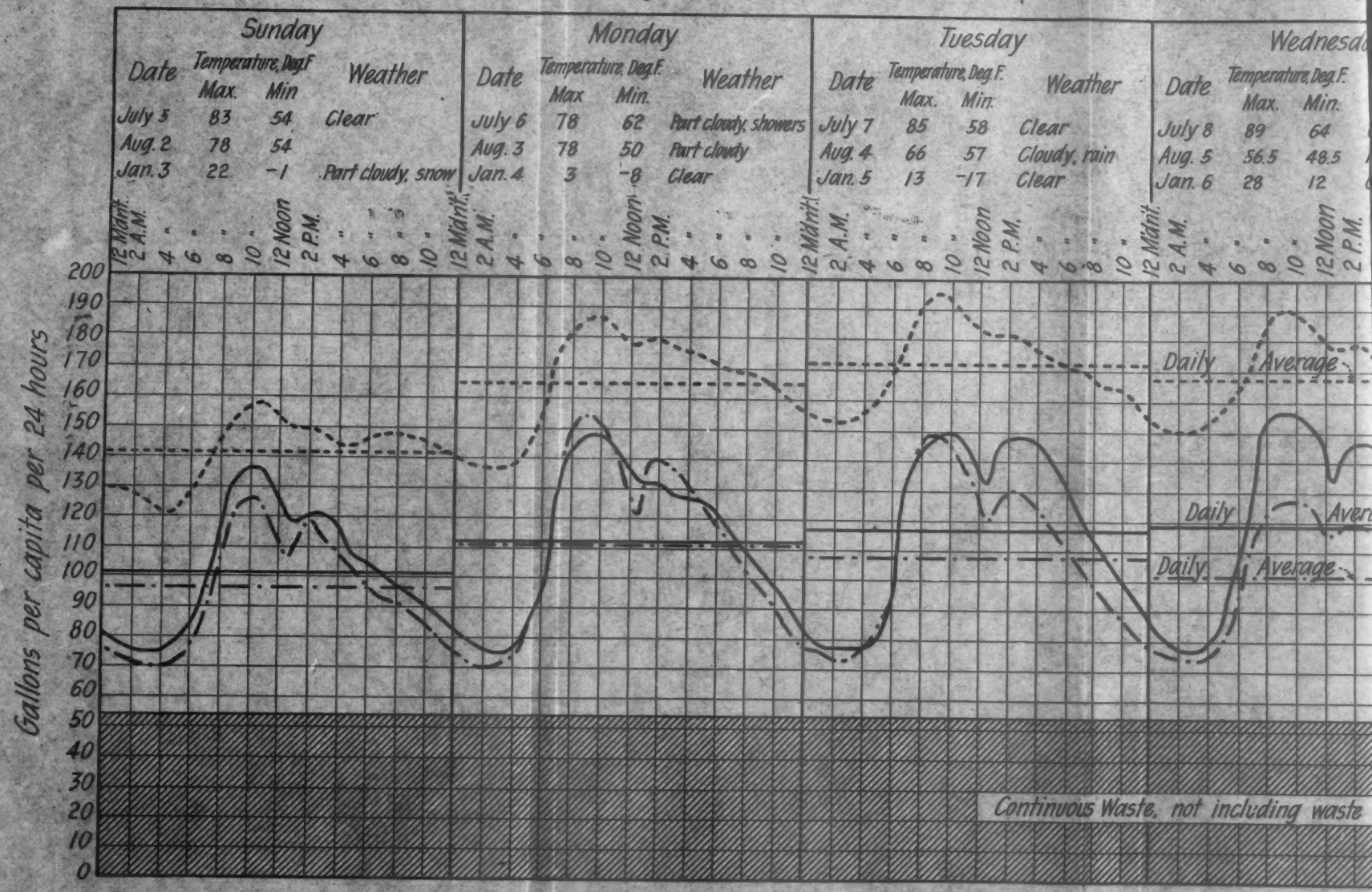


Diagram No. 1

of water used and wasted in the
Metropolitan Water Works.
Percentage of total population of district

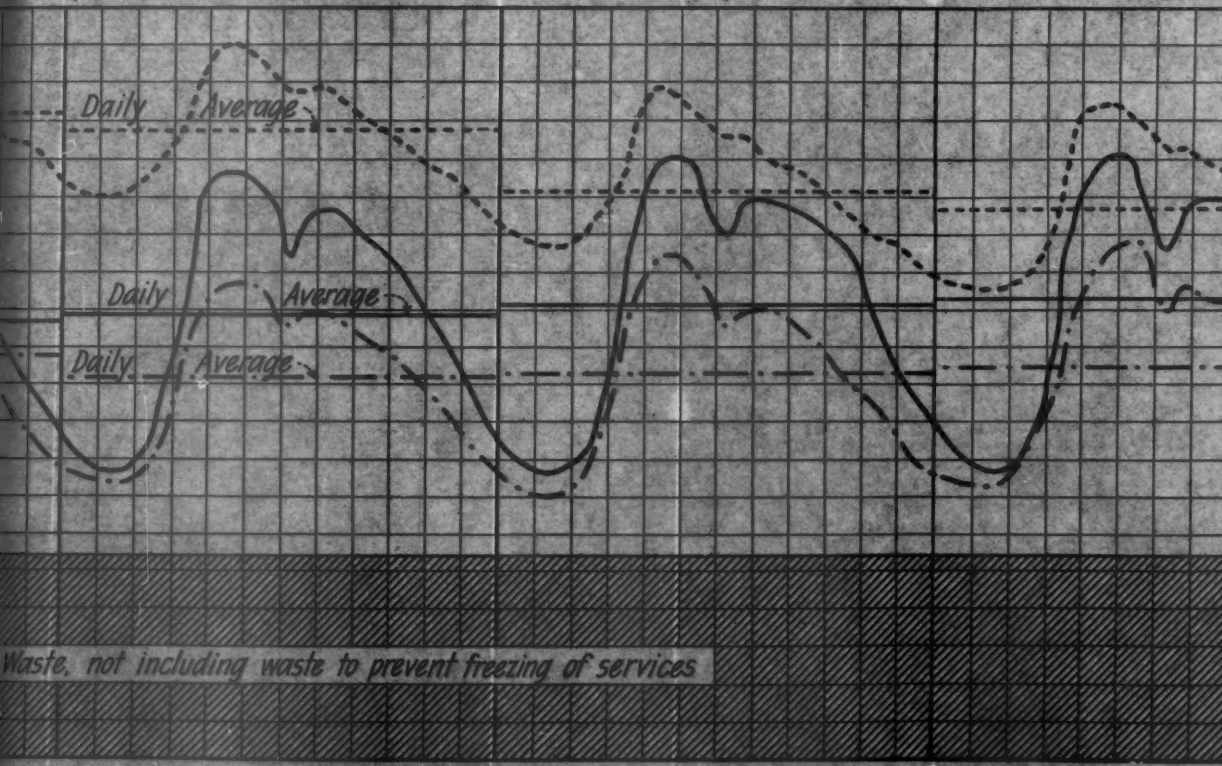
Hourly Variation in the Consumption of Water in the M


Sunday
Date | Temperature, Deg.F Max. | Min | Weather
July 3 | 83 | 54 | Clear
Aug. 2 | 78 | 54 |
Jan. 3 | 22 | -1 | Part cloudy, snow
Monday
Date | Temperature, Deg.F Max | Min. | Weather
July 6 | 78 | 62 | Part cloudy, showers
Aug. 3 | 78 | 50 | Part cloudy
Jan. 4 | 3 | -8 | Clear
Tuesday
Date | Temperature, Deg.F. Max. | Min. | Weather
July 7 | 85 | 58 | Clear
Aug. 4 | 66 | 57 | Cloudy, rain
Jan. 5 | 13 | -17 | Clear
Wednesd
Date | Temperature, Deg.F. Max. | Min.
July 8 | 89 | 64
Aug. 5 | 56.5 | 48.5
Jan. 6 | 28 | 12
12 Midnt. 2 A.M. 4 " 6 " 8 " 10 " 12 Noon 2 P.M. 4 " 6 " 8 " 10 " 12 Midnt.
Gallons per capita per 24 hours
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
Daily Average
Daily Aver
Daily Average
Continuous Waste, not including waste

of Water in the Metropolitan District. (From Venturi Meter Records, 1903-

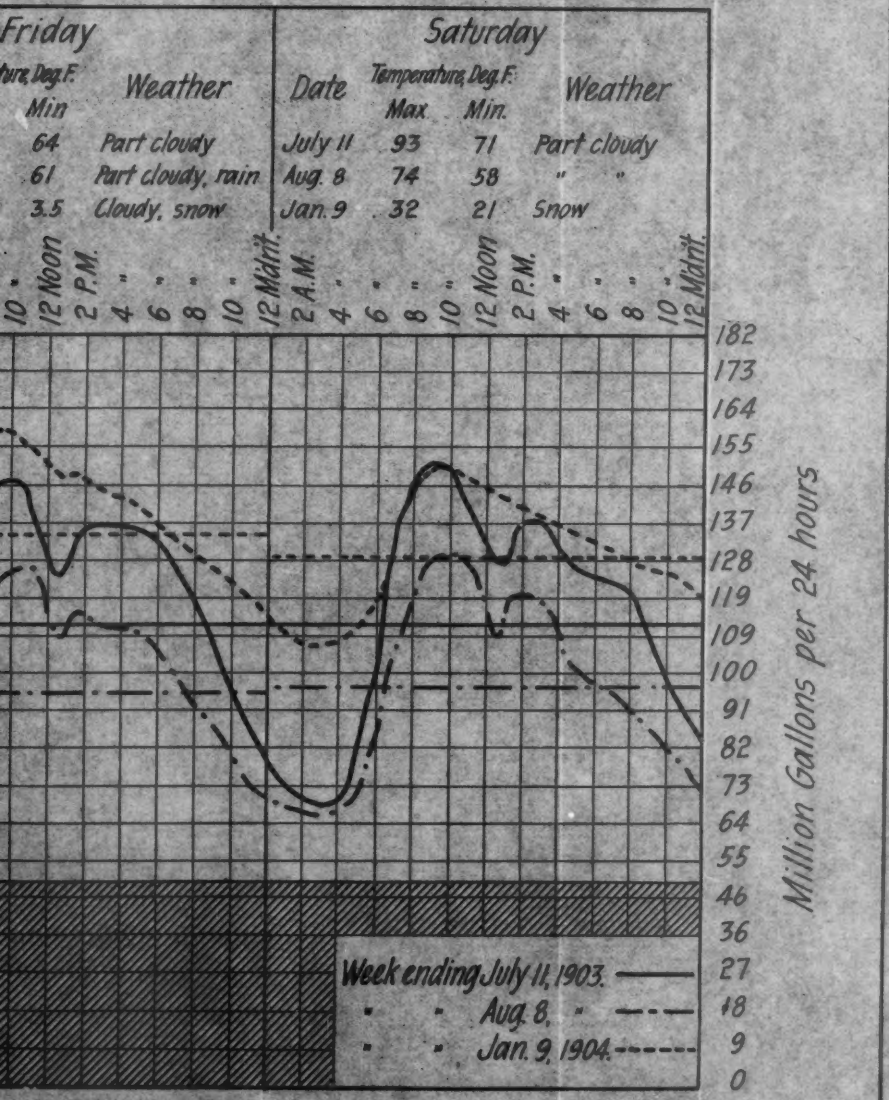
Wednesday				Thursday				Friday			
Date	Temperature, Deg. F. Max.	Min.	Weather	Date	Temperature, Deg. F. Max.	Min.	Weather	Date	Temperature, Deg. F. Max.	Min	
July 8	89	64	Clear	July 9	95	67	Clear	July 10	95	64	P
Aug. 5	56.5	48.5	Rain	Aug. 6	57.5	49	Cloudy, rain	Aug. 7	76.5	61	Pa
Jan. 6	28	12	Cloudy	Jan. 7	31	18	Part cloudy	Jan. 8	31	3.5	Cl

12 Midnt. 2 A.M. 4 " 6 " 8 " 10 " 12 Noon 2 P.M. 4 " 6 " 8 " 10 " 12 Midnt. 2 A.M. 4 " 6 " 8 " 10 " 12 Noon 2 P.M. 4 " 6 " 8 " 10 " 12 Midnt. 2 A.M. 4 " 6 " 8 " 10 " 12 Noon 2 P.M.



rds, 1903-4.)

Diagram No. 2.


Friday
Saturday
Temperature, Deg. F.
Min
Weather
64 Part cloudy
61 Part cloudy, rain
3.5 Cloudy, snow
Date
Max
Min
Weather
July 11 93 71 Part cloudy
Aug. 8 74 58 " "
Jan. 9 32 21 Snow
10 " 12 Noon 2 P.M. 4 " 6 " 8 " 10 " 12 Midnt. 2 A.M. 4 " 6 " 8 " 10 " 12 Noon 2 P.M. 4 " 6 " 8 " 10 " 12 Midnt.
182 173 164 155 146 137 128 119 109 100 91 82 73 64 55 46 36 27 18 9 0
Million Gallons per 24 hours
Week ending July 11, 1903.
Aug. 8, "
Jan. 9, 1904.

generally estimated. This fact is proved by the results obtained where water supplied to individual takers is measured, and can be compared with the total quantity supplied to the city or town. In the Metropolitan District in the town of Milton the water supplied to every taker is metered, including that used for street watering and other public purposes. In Belmont all supplies are metered, and a careful record is kept of the number of loads of water used for street watering. The total quantity of water delivered into the pipes of each town has been measured by means of Venturi meters, and, if the meters through which water is supplied to individual takers record accurately the water passing through them, the difference between the quantity recorded by the local meters and that delivered into the pipes of the town must represent the leakage from the street mains and service pipes.

The results of the observations made in these towns are as follows: —

TOWNS.	Gallons per Day.			Per Cent. unaccounted for.	Gallons per Day unaccounted for per Mile of Pipe.
	Delivered into Pipes of Town.	Metered to Consumer.	Unaccounted for.		
Milton, April, May, June, ...	325,100	216,300	108,800	33.5	3,110
Milton, July, August, September, . .	328,000	199,100	128,900	39.3	3,680
Belmont, March 15 to May 15, . . .	171,500	135,300	36,200	21.1	2,130
Belmont, May 15 to September 15, . .	230,500	145,000	85,500	37.1	4,780

In both of these towns meters have been used but a few years, and it does not seem probable that the loss in registration of the meters can be more than 2 or 3 per cent.

Similar results have been obtained in every city and town where the water supply to individual takers has been metered. In the following cities and towns meters are in use on all or a very large percentage of the services, but in every case a large percentage of the water delivered into the mains from the reservoir or pumps is unaccounted for by the meters.

TABLE No. 13.

CITY OR TOWN.	DELIVERED INTO MAINS.			METERED TO CONSUMERS, OR OTHERWISE ACCOUNTED FOR.		Per Cent. unaccounted for.	Gallons per Day unaccounted for per Mile of Pipe.
	Per Cent. of Taps metered.	Daily Average (Gallons).	Gallons per Consumer.	Gallons.	Gallons per Consumer.		
Brockton, . .	90.0	1,362,470	36.0	902,120	22.0	32.3	6,200
Ware, . .	100.0	338,180	44.0	203,430	26.5	39.8	11,200
Worcester, . .	94.5	8,094,840	68.0	4,331,030	39.0	46.5	20,800
Wellesley, . .	100.0	257,000	50.0	150,000	29.0	41.5	3,450
Yonkers, N. Y.,	100.0	4,540,900	89.0	2,463,490	42.7	45.7	23,340
Fall River, . .	96.0	4,365,060	40.5	3,430,300	32.0	21.5	10,000
Woonsocket, R.I.	86.7	989,420	28.6	762,380	22.0	23.0	4,370

In Belmont and Milton the quantity unaccounted for by the house meters varied from 2,130 to 4,780 gallons per mile of pipe per day, while in the cities and towns given in the above table the corresponding quantities vary from 3,450 to over 23,000 gallons. It is possible that in some instances the quantity delivered into the mains is overestimated, but there is no doubt that in the majority of cities there is a large leakage from mains and services. The opportunities for leakage from pipes buried underground are great, and the chances for their discovery are in most cases comparatively small. In the Metropolitan Water District there are 1,457 miles of pipes, on which there are 750,000 leaded joints from which leakage may occur. Leaks of considerable magnitude often remain undiscovered for months, the water escaping into the ground or into a brook or sewer. Several years ago, while Deacon waste-water meters were being used in Boston to detect leaks, several 4-inch and 6-inch cast-iron pipes were found broken, from which the water was escaping unseen into the sewers. In a number of instances this leakage was at the rate of 24,000 gallons per day, and in one instance 100,000 gallons per day were found to be running into a sewer from a 6-inch pipe which was broken entirely off.

A very forcible illustration of this source of waste has been furnished in the town of Stoneham. During the first six months of the year 1902 about 800,000 gallons per day were supplied to the town. As this quantity appeared larger than was needed for legitimate use, an investigation was instituted for the purpose of learning where the

water was used, with the result that four leaks in the street mains were found, which gave no surface indications. After these were repaired the consumption of water fell to 330,000 gallons per day, indicating that 470,000 gallons per day had been wasting from a few unseen defective pipes.

On the Boston works several large leaks in mains and service pipes have been discovered during the past year by means of the Deacon waste-water meters. The aggregate waste from eight of these was about 27,000 gallons per hour, equivalent to 648,000 gallons per day. In Arlington, Chelsea and Medford leaks from defective joints in the street mains have been discovered from which water was wasting at rates of from 1,000 to 2,000 gallons per hour, without any indications being given on the surface.

Tests have been made in Melrose to determine the amount of water leaking from the mains and services, by measuring with a meter the rate of flow into the pipe supplying certain streets while all the stop cocks on the house services were closed. These tests were made during the night, when the legitimate use was very small. The result of these measurements was as follows: —

Table No. 14.

Length of Main	Size (Inches).	Number of Service Pipes.	Leakage from Mains (Gallons per Hour).	Leakage and Use in Houses (Gallons per Hour).
1,000 feet,	6	20	1,035	180
600 feet,	6	13	250	290
1,000 feet,	6	22	225	70
400 feet,	6	10	675	45
500 feet,	6	9	–	25
1,150 feet,	4	21	1,080	270
350 feet,	–	8	–	90
700 feet,	6	14	–	180
1,550 feet,	6	21	180	520
1,000 feet,	–	22	–	270
600 feet,	8	12	–	180
1,250 feet,	14	33	45	270

The total leakage from less than 2 miles of pipes was 3,490 gallons per hour, or at the rate of 43,770 gallons per mile of pipe per day.

If, as has been shown by numerous examples, from 50,000 to 100,000 gallons of water per day can run into the ground continuously for months from a single leak in a main or service pipe, and give no indication on the surface of the ground, it is reasonable to conclude that there are, on the 750,000 joints in the street mains and the 150,000 service pipes, many smaller leaks, which, being smaller, are not easily discovered, but which in the aggregate waste a large quantity of water. Some water is wasted from street mains through carelessness in the manipulation of blow-off gates by department employés, and by the extravagant use of water for flushing sewers. Several years ago a blow-off valve was carelessly left open in Boston, and water ran for several days into a sewer at the rate of 3,000,000 gallons per day. In flushing water pipes and sewers much larger quantities are often used than are necessary for accomplishing the results desired, but it is not thought that the aggregate amount wasted in this way is large.

The tests which have been made in the several municipalities of the Metropolitan District tend to show that the leakage from the street mains and services is very large, and that from 10,000 to 15,000 gallons per mile of street main escape each day into the ground or into some underground channel. If this estimate is correct, the total leakage from the mains and services is from 15,000,000 to 22,500,000 gallons per day, — equivalent to from 16.5 to 25 gallons per inhabitant.

Waste from Pipes and Fixtures on Premises of Water Takers.

Waste from pipes or fixtures on premises of water takers is due either to defective plumbing or to permitting the water to run from open fixtures, either negligently or wilfully. Where the amount paid for water is not dependent upon the quantity of water used, the average water taker pays little attention to the condition of the plumbing on his premises; and, so long as the leaking fixtures cause no damage to his property, they are seldom repaired unless discovered by inspectors of the Water Department. For this reason the amount of waste from defective fixtures in cities where meters are not used depends largely upon the thoroughness with which the house-to-house inspection is done by the local authorities.

The greatest source of negligent waste from defective fixtures is undoubtedly the ball cock which controls the flow of water into

tanks supplying water-closets and other fixtures. The ball cock seldom remains tight more than a few months, and when defective allows a constant stream of water, often of considerable size, to flow unseen, though not always unheard, to the sewer. Although the ball cock is more liable than any other plumbing fixture to be the cause of waste, its inspection is more difficult than that of other fixtures, the tanks being generally placed in inaccessible places in buildings. Unless the inspection is very thoroughly performed, the greatest source of this kind of waste is therefore apt to be overlooked. Nevertheless, more tank fixtures are reported defective than any other class.

The following figures, taken from the annual reports of the Boston Water Department, show the results of inspections made during the past seven years: —

	1897.	1898.	1899.	1900.	1901.	1902.	1903.
Number of fixtures in use,	697,640	617,721	644,468	653,189	689,973	698,803	-
Tank fixtures leaking,	959	7,110	10,539	6,035	4,024	6,160	10,888
Faucets leaking,	521	4,655	7,995	2,634	1,963	3,282	5,086
Water-closets leaking,	-	1,080	4,887	1,091	199	223	294
Pipes leaking,	120	413	1,179	362	249	268	426
Wilful waste,	2	164	113	42	22	67	5

The differences between the number of leaks reported in different years are probably due to differences in the thoroughness of the inspection, rather than to the condition of the plumbing.

The results of inspections in several other cities and towns are given as follows: —

CITY OR TOWN.	Taps, Sinks, Bowls, Baths and Wash Trays.		Water-closets and Tanks.	
	Number in use.	Number found leaking.	Number in use.	Number found leaking.
Chelsea,	23,232	1,006	8,813	1,872
Everett,	22,680	548	6,368	1,138
Revere,	8,104	126	2,642	579
Somerville,	-	757	-	1,404
Winthrop,	6,803	69	2,296	101

To a greater degree than in the case of the street mains does the leakage from water fixtures take place from a very large number of small openings which permit of a constant flow. Few people realize that sufficient water will flow, in twenty-four hours, through an orifice of no greater diameter than an ordinary lead pencil, under the average pressure which exists in the pipes throughout the Metropolitan District, to furnish an ample domestic supply for 360 persons; and that in the same time more water will leak through an orifice the size of an ordinary pin than would be used by a fairly economical family of five persons. It is the continual running of thousands of little streams which causes the greater part of waste on the premises of the water takers.

Wilful Waste.

During the winter season large quantities of water are drawn from the pipes by water takers for the purpose of preventing the freezing of water in the house piping; and throughout the year faucets and water-closet fixtures are left or fastened open by water takers for the purpose of flushing water-closets and drain pipes, or in order that the water at the faucet may be constantly kept cool. The legitimate use of water is no larger during the winter season than during the months of November and April, but the actual use in the Metropolitan District is much larger during cold weather than during any other season of the year.

The average use for the months of November and April, compared with the use during intervening months for the past three years, was as follows: —

YEAR.	Daily Average (Gallons).		Difference wasted to prevent freezing of Water in Pipes (Gallons per Day).	Daily Number of Gallons per Capita wasted (Yearly Average).
	November and April.	December, January, February and March.		
1900-01, . . .	90,322,000	104,878,000	14,556,000	5.74
1901-02, . . .	99,317,000	111,417,000	12,100,000	4.61
1902-03, . . .	104,950,000	121,589,000	16,639,000	6.16

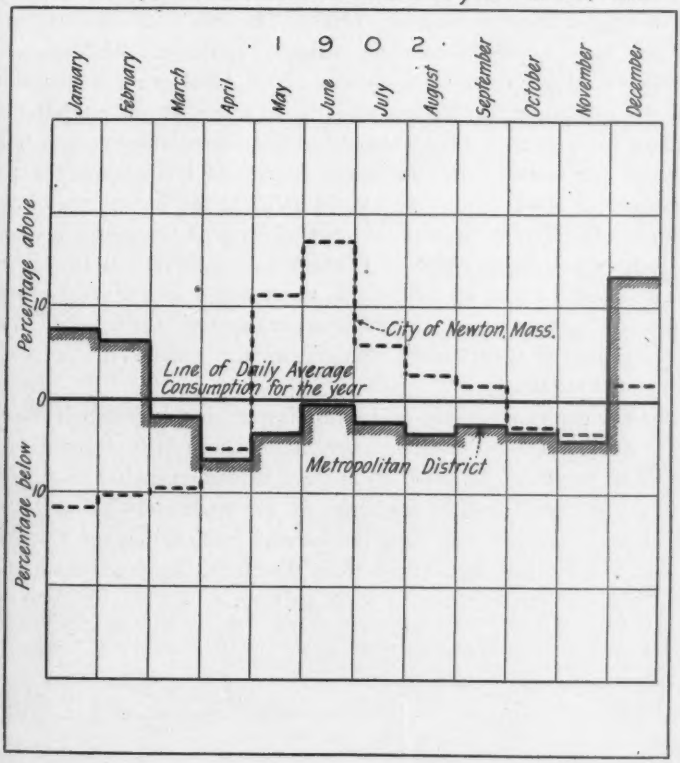
In the cities where meters are in general use, waste of this character does not occur to any great extent, as each property owner is pecuniarily interested so to arrange the plumbing in his buildings

that it does not become necessary to allow water to run in order to prevent it from freezing.

In the district supplied by the Metropolitan Works the use of water during the winter months is much larger than at any other season of the year; while in the city of Newton, where meters are in general use, the minimum use occurs during the winter. This is illustrated by Diagram No. 3.

Diagram No.3

Diagram showing percentage of variation from the daily average consumption of water for the several months of the year 1902 in the Metropolitan District and in the City of Newton, Mass



The effect of cold weather upon the use of water is illustrated very forcibly on Diagram No. 2, on which is shown the rate of

consumption from the Metropolitan Works during each hour of the week ending January 9, 1904. On Tuesday and Wednesday, which were the coldest days of the week, the consumption was about 60,000,000 gallons per day greater than during corresponding days in the month of August; and the lowest rate at which water was drawn from the pipes during the night was 150 gallons per capita, — an amount greater than the maximum rate of use during the corresponding days in August.

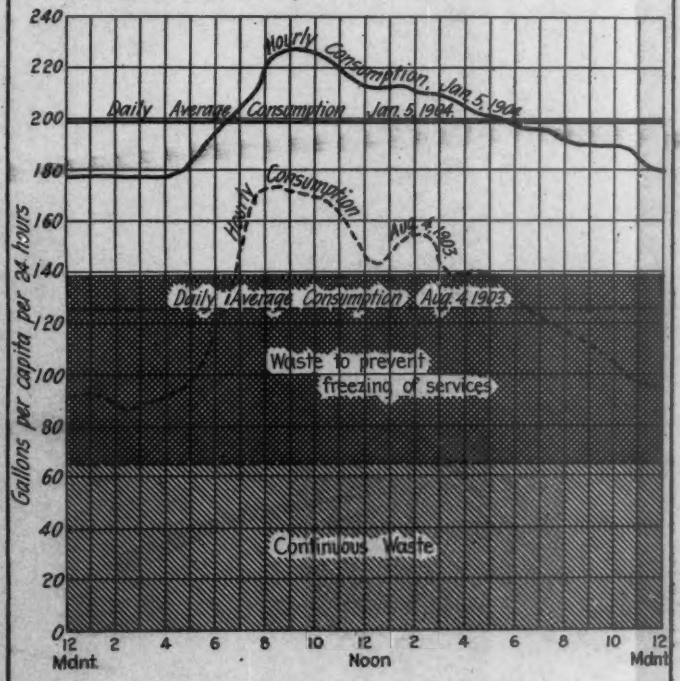
The amount wasted during extremely cold weather, as well as the effect of meters in controlling waste, is very forcibly illustrated by diagrams Nos. 4, 5 and 6, which show graphically the use of water in Boston, Chelsea and Malden on January 5, 1904, compared with the use on a day in August, 1903. The cities of Malden and Chelsea have approximately the same population. Malden uses meters on 69 per cent. of its service pipes, Chelsea on 2 per cent. The per capita use in Malden on August 4 was 41 gallons, and in Chelsea 88 gallons. On January 5, 1904, when the average temperature for twenty-four hours was 2 degrees below zero, the per capita use in Malden increased to 57 gallons, and in Chelsea to 211 gallons. In Malden the increase caused by cold weather was about 16 gallons per capita, and in Chelsea 123 gallons. Between the hours of 2 and 4 A.M. on January 5, water was drawn from the pipes in Chelsea at the rate of 192 gallons per day for each inhabitant of the city, and in Boston the rate during the same hours was 178 gallons per capita.

The per capita waste caused by running water to prevent its freezing is largest in those districts where houses are of the cheaper class, but which are furnished with all modern conveniences for the use of water. The cold-weather waste during the week ending January 9, in Chelsea, Charlestown, East Boston and Somerville, was from 60 to 100 gallons per capita; while in Medford, Melrose, Arlington and Quincy it ranged from 15 to 20 gallons.

Diagram No. 4

Diagram showing Consumption of Water in the City of Boston during each hour of the day. Aug. 4, 1903 and Jan. 5, 1904.

Population 599,000. Per cent of services metered 5.27
Average temperature Aug. 4, 61° F.; Jan. 5, -2° F.



Diagram

Consumption of Water i

during each hou

Aug. 4, 1903 and

Population 36,000. Per ce
Average temperature Aug. 4, 61°

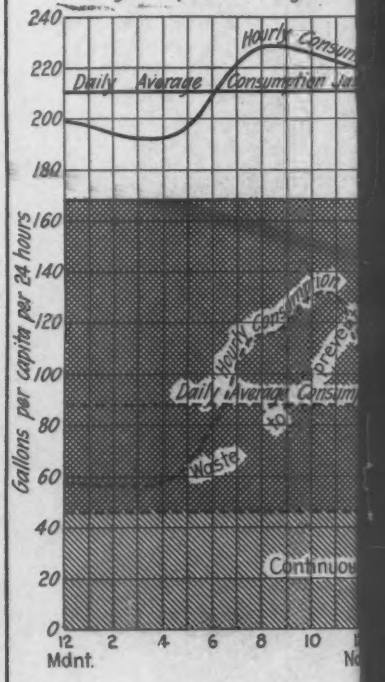


Diagram No. 5

Diagram showing Consumption of Water in the City of Chelsea during each hour of the day. Aug. 4, 1903 and Jan. 5, 1904.

Population 36,000. *Per cent of services metered 2.12*

Average temperature Aug. 4, 61° F.; Jan. 5, -2° F.

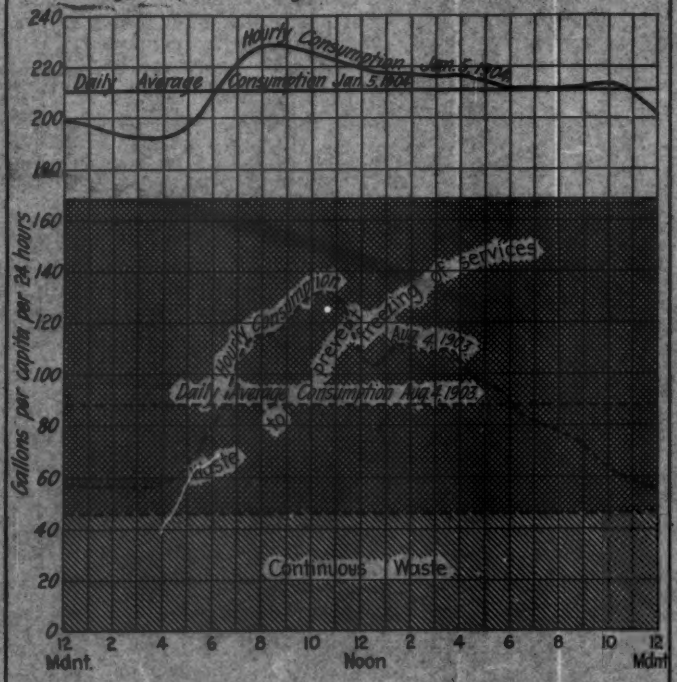


Diagram No. 6

Diagram showing Consumption of Water in the City of Malden during each hour of the day Aug. 4, 1903 and Jan 5, 1904

Population 37,000 *Per cent of services metered 69.20*
Average temperature Aug. 4, 61° F., Jan. 5, -2° F.

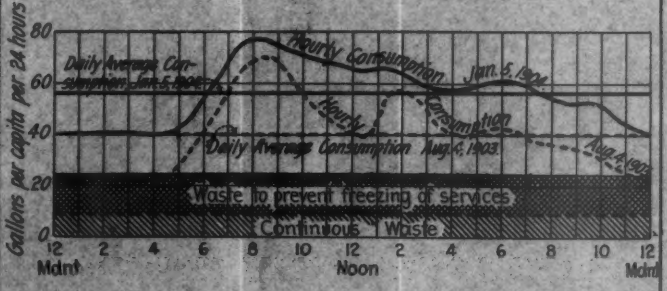
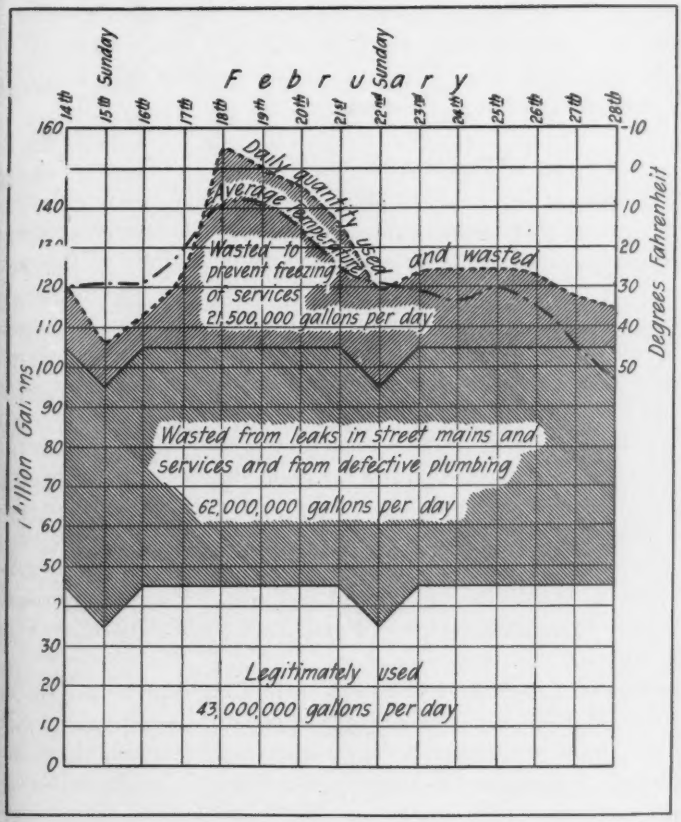


Diagram No. 7 shows the consumption of water in the city of Boston during a cold period in February, 1903.

Diagram No. 7

Diagram showing daily quantity of water used and wasted in Metropolitan Water District. Feb. 14 to 28, 1903.



The daily average consumption of water previous to the cold weather was about 105,000,000 gallons per day. On February 18, 155,500,000 gallons were used, of which 50,500,000 gallons, equivalent to 57 gallons per capita of the entire population of the District,

were wasted for the purpose of preventing the freezing of service pipes and plumbing.

It is the practice of some water takers to allow water to run continuously from water-closets, for the purpose of cleansing house drains; others permit the water to run from the kitchen faucet, in order that the water may not become warm in the pipes, and some even use a constant stream of water, instead of ice, for the purpose of preserving food. Some water is wasted by each of these methods, but they are sources of waste which are not easily detected by house-to-house inspection, and no attempt has been made to determine the exact amount wasted from these causes.

Prevention of Waste.

Much waste of water may be prevented by the inspection of house plumbing, and this method, aided by the use of Deacon meters, accomplished good results for several years in the city of Boston. The use of these meters and the work of inspection were begun in 1883, and in 1884 the consumption had been reduced from 91.5 gallons to 68 gallons per capita. The inspection was continued about ten years, but with decreasing diligence; and for ten years previous to 1903 little attention was given to the prevention of waste. In order to obtain facts as to the present condition of affairs, measurements of the consumption during the night have been made by the Boston Water Department during the past year in some of the residential districts of the city by the use of the Deacon meters; and where the measurements indicated a large waste of water, efforts have been made to locate and prevent the same. The measurements were made between the hours of 1 and 4 A.M., when the legitimate use in residential districts is least.

The Deacon meters were first used in the Charlestown district in 1881, and in Table No. 15 the results of measurements made at that time are given, also other measurements made in 1893, about the time active inspection was stopped, as well as those made during the present year.

TABLE No. 15.

POPULATION OF DISTRICT.			NIGHT RATE OR WASTE (GALLONS PER CAPITA PER DAY).			
1881.	1893.	1903.	Before Inspection, 1881.	After Inspection, 1881.	1893.	1903.
3,675	4,700	4,725	39.0	13.7	24.8	52.8
2,170	2,925	2,975	33.1	13.2	23.8	52.2
1,875	2,325	2,425	44.6	15.1	21.2	63.3
2,030	3,125	3,250	43.2	20.2	40.0	88.0
1,880	1,800	1,800	42.2	22.3	26.7	70.6
1,790	2,150	2,400	53.3	17.8	27.9	53.0
2,540	3,300	3,450	31.9	19.2	26.2	55.7
15,960	20,325	21,025	41.8	17.0	27.3	61.5

There has been very little change in the character of the population or of the plumbing in these sections during the twenty-two years since the first tests were made. By thorough inspection the waste was reduced in 1881 from 41.8 to 17 gallons per capita. Between 1881 and 1893 the inspection was less thoroughly performed, and the waste increased to 27.3 gallons. Since 1895 very little attempt has been made to detect and prevent waste, with the result that the night rate has increased to 61.5 gallons per capita.

The increase in waste in other sections of the city of Boston during the past four years is shown in Table No. 16: —

TABLE No. 16.

DISTRICT.	Section.	POPULATION.		RATE OF USE BETWEEN 1 AND 4 A.M. (GALLONS PER CAPITA PER DAY).		
		1899.	1903.	1899.	1903.	Increase.
Roxbury, . .	Walnut Avenue, Section 1, . .	2,100	2,150	42.2	81.5	39.3
Roxbury, . .	Walnut Avenue, Section 2, . .	2,200	2,200	31.7	73.1	41.4
Roxbury, . .	Walnut Avenue, Section 3, . .	2,600	2,700	38.4	48.0	9.6
Roxbury, . .	Walnut Avenue, Section 4, . .	1,400	1,500	58.3	116.8	58.5
Roxbury, . .	Warren Street, No. 1, Section 1,	2,150	2,150	88.8	84.8	—4.0
Roxbury, . .	Warren Street, No. 1, Section 2,	1,100	1,100	30.5	43.6	13.1
Roxbury, . .	Warren Street, No. 1, Section 3,	2,000	2,000	30.0	62.4	32.4
Roxbury, . .	Warren Street, No. 2, Section 1,	2,550	2,650	52.7	56.2	3.5
Roxbury, . .	Warren Street, No. 2, Section 2,	2,800	2,800	54.0	65.1	11.1

TABLE NO. 16 — *Concluded.*

DISTRICT.	Section.	POPULATION.		RATE OF USE BETWEEN 1 AND 4 A.M. (GALLONS PER CAPITA PER DAY).		
		1899.	1903.	1899.	1903.	Increase.
Roxbury,	Warren Street, No. 2, Section 3,	1,650	1,400	31.3	82.3	51.0
Roxbury,	Cedar Street, Section 1,	2,100	2,150	40.0	82.6	42.6
Roxbury,	Cedar Street, Section 2,	2,250	2,400	37.8	79.0	41.2
Roxbury,	Cedar Street, Section 3,	2,400	2,450	51.5	58.8	7.3
Roxbury,	Cedar Street, Section 4,	2,500	2,250	32.6	66.1	33.5
Roxbury,	Lamartine Street, Section 1,	2,700	2,700	41.8	106.7	64.9
West Roxbury,	Spring Park Avenue, Section 1,	3,950	4,175	27.9	50.0	22.1
West Roxbury,	Spring Park Avenue, Section 2,	1,800	1,900	60.0	53.0	—7.0
West Roxbury,	Burroughs Street, Section 1,	1,200	1,450	55.0	72.7	17.7
West Roxbury,	Burroughs Street, Section 3,	650	750	59.0	54.4	—4.6
City proper,	Bowdoin Street, Section 1,	1,600	1,550	76.5	102.2	25.7
City proper,	Bowdoin Street, Section 2,	2,400	2,700	58.0	97.8	39.8
City proper,	Joy Street, Section 1,	2,500	2,850	28.3	26.0	—2.3
City proper,	Joy Street, Section 2,	2,000	5,000	58.8	69.6	10.8
South Boston,	Fifth Street, Sections 1 and 2,	5,600	5,700	41.7	61.0	19.3
		54,200	58,675	-	-	-

It is very evident, from an inspection of the above tables, that at the present time a very large quantity of water is being wasted, and that any system of house-to-house inspection must be continuous in order to be effective. House-to-house inspection is open to the objection that the constant visits of inspectors are annoying to the householders.

While these investigations were in progress, several large leaks were located from the street mains and services; and house-to-house inspection on streets where much waste was noted disclosed in some cases that the house plumbing was in very poor condition. On one street, where the night rate was 5,200 gallons per hour, the inspection disclosed ball cocks wide open, and every faucet in three houses running large streams, the washers being entirely gone. On another street, in fifteen out of sixteen houses examined, the ball cocks were defective, and wasting large streams of water.

In addition to the large leaks which were located in the street mains and service pipes, there are no doubt many smaller leaks still undiscovered; but the inspection proved that the house plumbing is

very defective, and the greater part of the present enormous waste in Boston is probably due to waste on the premises of the water takers.

Effect of using Meters.

The most certain means of detecting waste, and the most effectual means of preventing the extravagant use and waste of water, is that of measuring the water supplied to each municipality, district or individual water taker, and obliging each municipality and individual to pay for water in proportion to the quantity used. Where meters are in use, each water taker finds it to be for his interest to see that the plumbing fixtures which he uses are of the best quality, and that they are kept in repair; that the pipes in his buildings are so located that they will not freeze during cold weather; and that his family or employés are not wasteful in the use of water. The introduction of meters upon all old works has always been followed by a reduction in the quantity of water used; and in cities and towns where they have been introduced when the works were built, the per capita consumption is universally very low. The effect of the use of meters is well illustrated by a comparison between the per capita consumption of water in cities and towns where meters are in general use with that in those where water is paid for at schedule rates. Differences in climate, in character of business and in location, as affecting the available supply of water, often have a marked effect upon the consumption in different cities; but in the following table an attempt has been made to eliminate these differences, as far as possible.

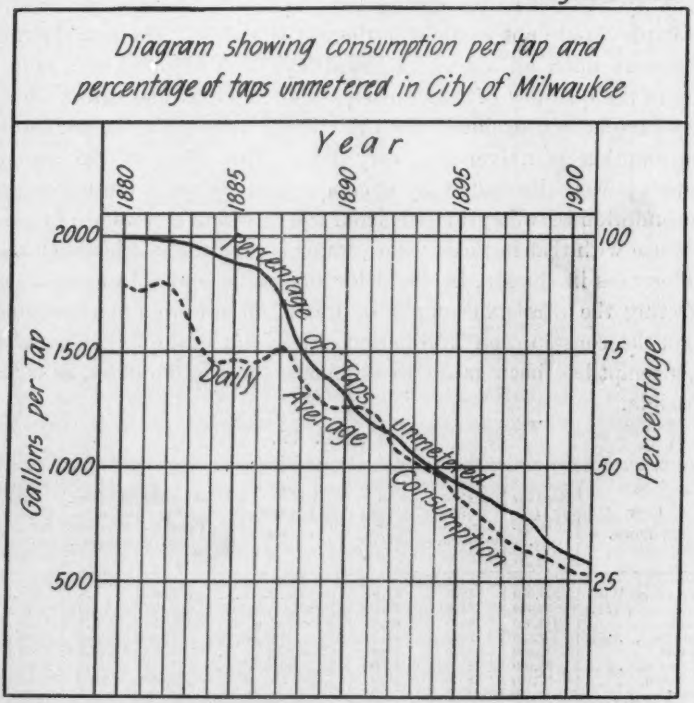
TABLE No. 17.

City or Town.	Number of Consumers.	Per Cent. of Services metered.	Consumption (Gallons per Day per Consumer).	City or Town.	Number of Consumers.	Per Cent. of Services metered.	Consumption (Gallons per Day per Consumer).
Milwaukee, Wis.,	308,000	80.0	81.0	Buffalo, N. Y.,	360,000	2.0	324.0
Providence, R. I.,	196,400	84.5	58.0	Indianapolis, Ind.,	169,100	6.0	79.0
Worcester,	119,350	94.5	68.0	New Haven, Ct.,	108,000	2.8	150.0
Fall River,	107,550	96.0	41.0	New Bedford,	61,000	18.0	104.0
Lowell,	100,000	65.0	57.0	Cambridge,	94,150	15.0	85.0
Lawrence,	65,000	83.0	53.0	Haverhill,	37,200	10.0	95.0
Brockton,	37,800	90.0	36.0	Lynn,	74,000	25.0	63.0
Newton,	35,400	86.0	54.0	Waltham,	24,550	6.0	99.0
Woonsocket, R. I.,	34,474	96.0	29.0	Salem,	36,250	3.0	79.0
Ware,	7,690	100.0	44.0	Montague,	6,150	2.0	73.0
Wellesley,	5,147	100.0	49.0	Dedham,	7,500	2.0	85.0
Reading,	4,385	100.0	33.0	Braintree,	5,980	1.0	91.0
	1,023,276	-	61.7		983,880	-	178.5

In the first four columns are given the statistics for twelve cities and towns where meters are in general use, and in the following columns corresponding data for an equal number of cities and towns of approximately equal size where few meters are used, but where the conditions as regards location and trade are generally similar. The average per capita consumption where meters are used is but little more than one-third of that in the unmetered cities.

The effect of the use of meters upon the consumption of water is very graphically illustrated by Diagram No. 8, which shows the daily number of gallons used per tap in the city of Milwaukee, and the percentage of unmetered taps for each of the past twenty-two years.

Diagram No. 8



It will be noticed that there has been a gradual reduction in the quantity of water used with the increase in the use of meters. In 1880, with no meters in use, 1,750 gallons were drawn from

each tap; in 1890, with about one-third of the taps metered, the quantity drawn from each was only 1,250 gallons; and in 1902, with 72 per cent. metered, the quantity used per tap was only 550 gallons.

During the past two years the Water Department in the city of Cleveland has been engaged in placing meters upon service pipes. At the end of the year 1902, 11,099 meters were in use on 56,816 services; and the daily average consumption for the year was 69,964,740 gallons. At the close of the year 1903 the number of meters had been increased to 25,193; and the daily average consumption for the year was 62,012,000 gallons. As a result of this work, the daily average consumption for the year 1903 was about 8,000,000 gallons per day less than in 1902, and the greater part of this reduction was no doubt due to the meters set during the previous year.

Effect of Meters upon the Poor.

The fear has been sometimes expressed, by those who have not given the subject careful study, that the use of water meters will have the effect of reducing the use of water by the poorer class of takers below an amount necessary for health. The experience in the cities and towns using meters does not indicate that there need be any fear of such a result. It is the usual custom, where meters are used, to make a uniform minimum charge of from $10 to $12 to each water taker, for which sum the taker is entitled to use the quantity for which an equal charge would be made at meter rates. The yearly schedule rate paid by water takers in the different municipalities of the Metropolitan District for the use of one faucet and a water-closet is generally from $9 to $11, and the rate for a single faucet is $5. For $10 per annum per taker, every person in a family of average size, if supplied by meter at the rate of 14 cents per 100 cubic feet, which is the rate generally in force throughout the District, will have the privilege of using 30 gallons, or twelve pailfuls of water per day, which experience shows to be ample for domestic use. In many municipalities where water used for domestic purposes is metered, exception is made in cases where premises are supplied through a single faucet, and the schedule rate remains in force. There appears to be no reason, however, why a minimum rate of $5 per year should not be made for premises of this kind supplied by meter. Experience shows that the majority of the water

takers using water for domestic purposes use less than the quantity to which they are entitled by the minimum charge.

In the city of Malden the minimum yearly charge is $12, for which sum each water taker is entitled to use 47,470 gallons, equivalent to 130 gallons per day, or 26 gallons per day for each member of a family of average size. In the year 1901 the total number of meters on domestic services was 3,490, and the daily average number of gallons used by each service was 112.8. The number using less than the minimum quantity was as follows: —

Cubic Feet per Year.	Number of Services.	Gallons per Day per Service.	Cubic Feet per Year.	Number of Services.	Gallons per Day per Service.
Less than 500, . . .	28	* 6.4	Between 3,000 and 4,000, .	566	72.0
Between 500 and 1,000, .	52	* 16.1	Between 4,000 and 5,000, .	560	92.0
Between 1,000 and 2,000, .	259	* 33.9	Between 5,000 and 6,300, .	621	114.0
Between 2,000 and 3,000, .	441	52.5		2,527	77.4

* Many of these were metered for but a portion of the year.

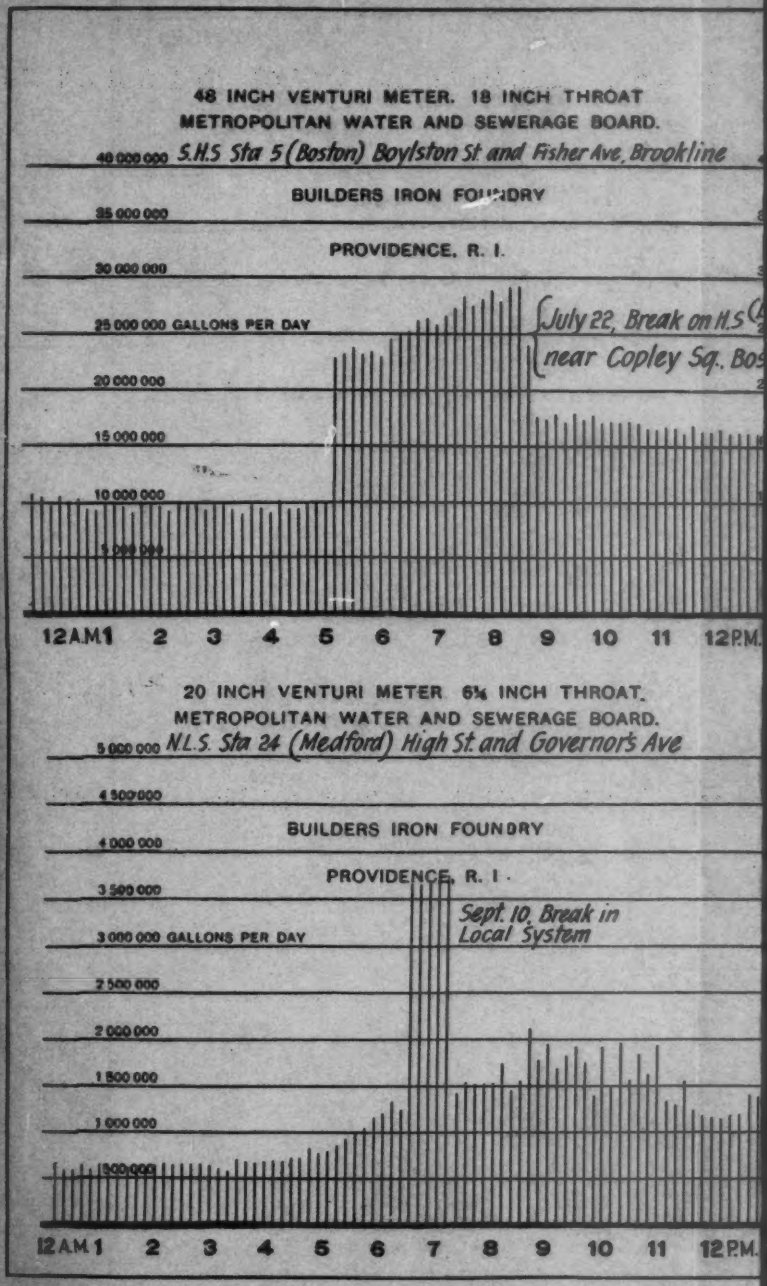
In the city of Providence the minimum charge is $10 per annum, for which each taker or service is entitled to use 91.32 gallons per day. In 1888 an analysis was made to show the number of takers using less than the quantity permitted by the minimum rate, with the following result: —

Cubic Feet Per Year.	Number of Services.	Gallons per Day per Service.	Cubic Feet per Year.	Number of Services.	Gallons per Day per Service.
Less than 1,500, . . .	167	30.74	Between 3,000 and 3,500, .	446	71.73
Between 1,500 and 2,000, .	237	40.99	Between 3,500 and 4,000, .	462	81.98
Between 2,000 and 2,500, .	361	51.23	Between 4,000 and 4,457, .	435	91.32
Between 2,500 and 3,000, .	445	61.48		2,553	66.70

The total number of meter accounts at this time, including those for trade, manufacturing and mechanical use, was 7,074, of which 5,110, or 72 per cent., paid less than $20 per year.

Use of Meters on Street Mains.

As has been already stated on previous pages, there is a large leakage from the pipes in the streets, and this cannot be detected ex-


48 INCH VENTURI METER. 18 INCH THROAT
METROPOLITAN WATER AND SEWERAGE BOARD.
S.H.S Sta 5 (Boston) Boylston St and Fisher Ave, Brookline
BUILDERS IRON FOUNDRY
PROVIDENCE, R. I.
40 000 000
35 000 000
30 000 000
25 000 000 GALLONS PER DAY
20 000 000
15 000 000
10 000 000
5 000 000
July 22, Break on H.S (
near Copley Sq., Bos
12 A.M. 1 2 3 4 5 6 7 8 9 10 11 12 P.M.
20 INCH VENTURI METER 6¼ INCH THROAT.
METROPOLITAN WATER AND SEWERAGE BOARD.
N.L.S. Sta 24 (Medford) High St and Governor's Ave
5 000 000
4 500 000
4 000 000
BUILDERS IRON FOUNDRY
3 500 000
PROVIDENCE, R. I.
3 000 000 GALLONS PER DAY
2 500 000
2 000 000
1 500 000
1 000 000
500 000
Sept. 10, Break in
Local System
12 A.M. 1 2 3 4 5 6 7 8 9 10 11 12 P.M.

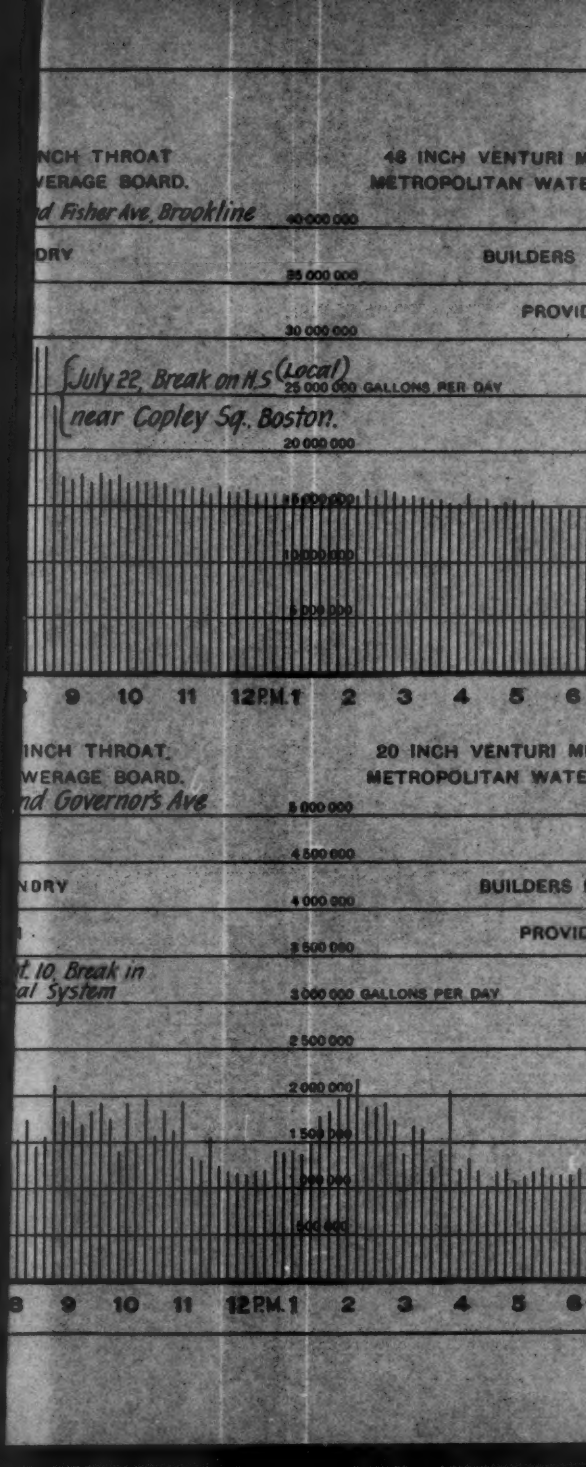

NCH THROAT
VERAGE BOARD.
d Fisher Ave, Brookline
48 INCH VENTURI M
METROPOLITAN WATE
ORY
BUILDERS
PROVID
July 22, Break on H.S (Local)
near Copley Sq. Boston.
40 000 000
35 000 000
30 000 000
25 000 000 GALLONS PER DAY
20 000 000
10 000 000
5 000 000
9 10 11 12 P.M. 1 2 3 4 5 6
INCH THROAT.
WERAGE BOARD.
nd Governor's Ave
20 INCH VENTURI M
METROPOLITAN WATE
5 000 000
4 500 000
NDRY
4 000 000
BUILDERS
PROVID
3 500 000
t. 10 Break in
al System
3 000 000 GALLONS PER DAY
2 500 000
2 000 000
1 500 000
8 9 10 11 12 P.M. 1 2 3 4 5 6

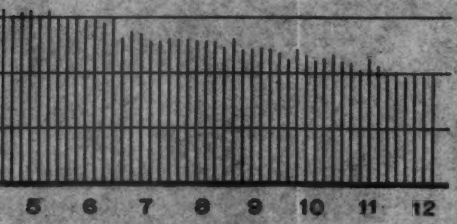
Diagram No. 9

VENTURI METER. 18 INCH THROAT.
TAN WATER AND SEWERAGE BOARD.

BUILDERS IRON FOUNDRY

PROVIDENCE, R. I.

AY



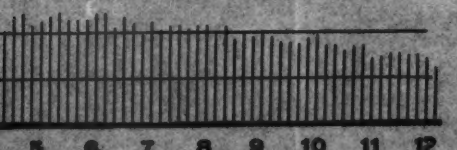
5 6 7 8 9 10 11 12

ENTURI METER. 6¼ INCH THROAT.
TAN WATER AND SEWERAGE BOARD.

BUILDERS IRON FOUNDRY

PROVIDENCE, R. I.

AY



5 6 7 8 9 10 11 12

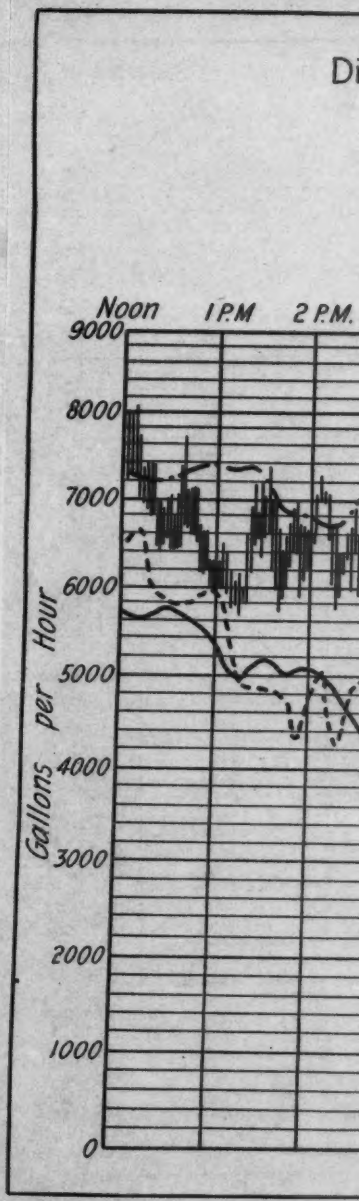
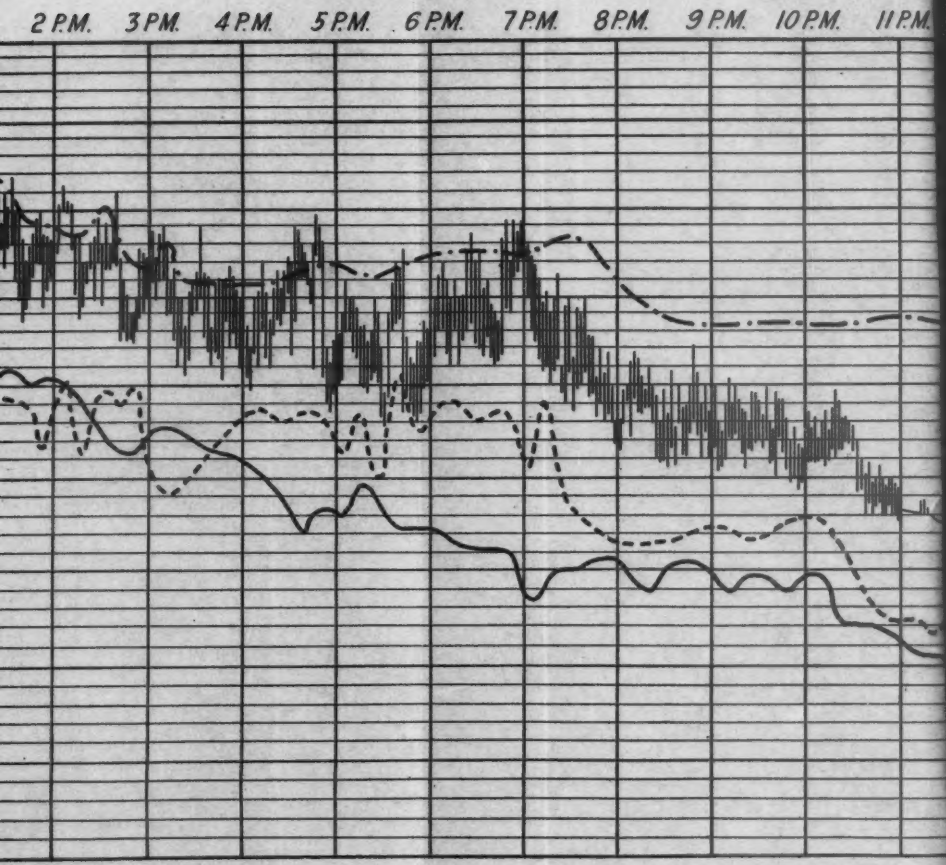

Noon
1 P.M
2 P.M.
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Gallons per Hour

Diagram showing Hourly Rate of Consumption in a Portio

Summ

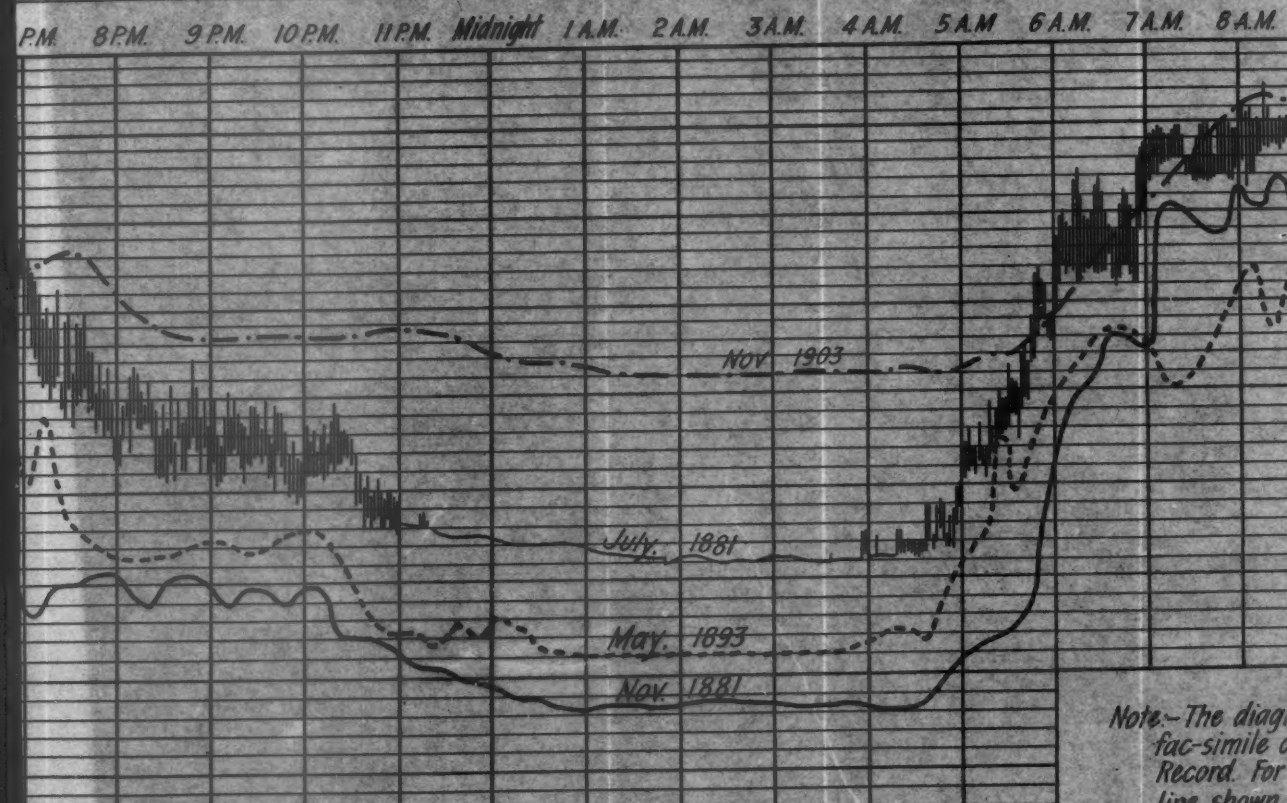
Date	Population	Rate, Gallons per Hour		
		Average for 24 hrs.	Night Rate (waste)	Aver
July, 1881	1880	5350	3300	
Nov. 1881	1880	3750	1740	
May, 1893	1800	4100	2200	
Nov. 1903	1825	6400	5200	



e of Consumption in a Portion (Section, Winthrop 2) of Charlestown District, City of Bos

Summary of Tests

Rate, Gallons per Hour		Gallons per capita per day		Remarks
Average for 24 hrs.	Night Rate (waste)	Average for 24 hrs.	Night Rate (waste)	
5350	3300	68.4	42.2	Before inspection
3750	1740	47.8	22.3	After two or three inspections
4100	2200	54.7	29.3	Inspection continued until July 1895
6400	5200	84.0	68.4	No inspection for 8 years

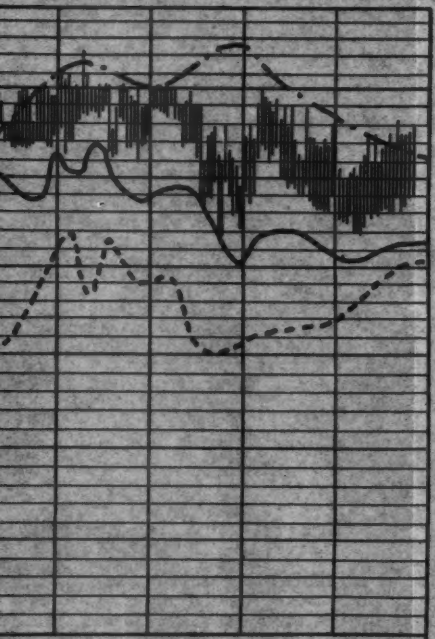


Note.—The diag
fac-simile
Record. For
line shown

Diagram No. 10

y of Boston.

8 A.M. 9 A.M. 10 A.M. 11 A.M. Noon

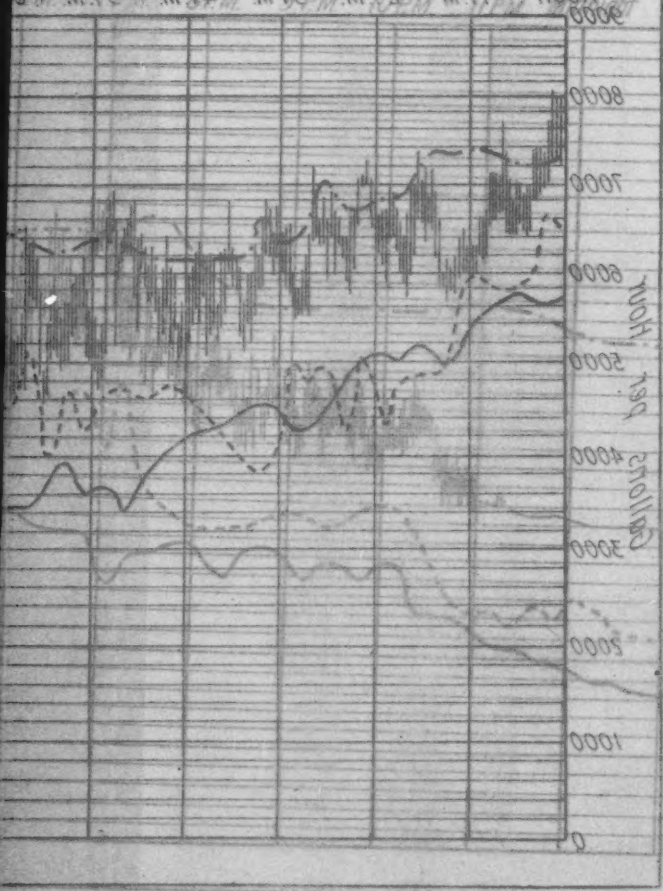


The diagram for July 1881 is a
-simile of the Deacon Meter
cord. For the other dates the
e shown is an average.

Diagram showing Hourly Consumption in a Portion (Section, ...

Summary of Tests

Date	Rate, Gallons per Hour		Gallons per capita	
	Average for 24 hrs.	Night Rate (wast...	Average for 24 hrs.	Nig...
July 1881	5350	3300	68.4	
Nov 1881	3150	1740	47.8	
May 1893	4100	2200	54.7	
Nov 1903	5400	5200	84.0	



cept in the aggregate, and cannot be prevented by measuring the water supplied to each taker. Underground leaks in the streets can be best located by placing meters on the street mains, in such a manner that districts containing from 2,000 to 5,000 persons can be isolated from the remainder of the pipe system. The type of meter used for buildings is not well adapted to this service, but either the Venturi meter previously described, or the Deacon waste-water meter, which has been used in Boston for detecting waste, can be used to good advantage. Both of these meters record the rate at which water is drawn through them, and by closing valves on the pipes, the leaks, both in mains and service pipes, can be located within narrow limits. The Deacon meter gives a continuous record of the rate of flow; the Venturi meter records the rate of flow at intervals of ten minutes.

Samples of the records made by both of these types of meters are shown on the following pages.

The Venturi meter records, shown on Diagram No. 9, are full size facsimiles of original records, showing the increased draft caused by leaks in street mains. On Diagram No. 10 is shown, on a slightly reduced scale, the facsimile of a record made by a Deacon meter in July, 1881, before any attempt had been made to prevent waste, together with records made at later dates. It will be noticed that the record of November, 1881, shows a line approximately parallel with the record made in the preceding July, indicating that the reduction due to stopping waste was continuous throughout the twenty-four hours. It is also noticeable that the draft during the day was but very little larger in November, 1903, than it was in July, 1881, twenty-two years before, while the night rate or waste in 1903 was the largest recorded.

By the most thorough inspection it is not practicable to prevent all underground waste of water, and the best results can only be obtained by a force of well-trained, conscientious employés. This condition of affairs is more or less difficult of attainment, but it is perfectly feasible to reduce the underground waste to from 10 to 15 gallons per capita, and the total waste, including that in buildings, to from 15 to 20 gallons.

Method of Assessment.

By the present method of apportioning the amount required to pay the interest, sinking fund requirements, and expenses of mainte-

nance and operation for the Metropolitan Water District, the city of Boston pays in the proportion that its valuation bears to the total valuation of the whole water district; and the remaining cities and towns pay the remainder of the required amount, one-third in proportion to their respective valuations and two-thirds in proportion to their respective populations, including, however, only one-sixth of the total valuation and one-sixth of the total population of any city and town which has not reached the safe capacity of its sources of supply, and has not made application for a supply of water. By this method of assessment the proportion paid by the several municipalities is not affected by the quantity used, and, although each municipality should be interested to keep the cost of constructing and maintaining works as small as possible, the inducement to prevent waste of water is general rather than special, especially in the smaller cities and towns. Under the present system, those cities and towns where the quantity of water used is kept within reasonable limits, either by the use of meters or by inspection, pay a higher rate for the water used than those where meters are not in use, and little or no attempt is made to prevent waste. This is shown by the following table (No. 18), giving the cost to each municipality of the water used during the year 1903. The quantity used has been determined from actual measurement during the last six months of the year, and estimated for the remaining time.

TABLE NO. 18.

CITY OR TOWN.	Amount of Assessment for 1903.	Estimated Quantity used (Million Gallons).	Cost per Million Gallons.
Boston,	$1,510,857 46	29,382.50	$51 42
Somerville,	77,288 43	2,120.65	36 45
Malden,	41,635 31	646.05	64 45
Chelsea,	39,877 54	1,277.50	31 21
Everett,	29,794 15	857.75	34 73
Quincy,	30,237 42	912.50	33 14
Medford,	24,654 86	602.25	40 05
Melrose,	17,815 34	511.00	34 86
Revere,	13,771 64	299.30	46 01
Watertown,	13,440 83	182.50	73 65
Arlington,	11,549 55	244.55	47 23
Milton,	14,813 20	120.45	122 79
Winthrop,	8,653 44	244.55	35 38
Stoneham,	7,523 04	164.25	45 80
Belmont,	5,701 23	80.30	71 00
Lexington,	5,733 77	87.60	64 47
Nahant,	3,211 08	51.10	62 84
	$1,856,558 29	37,784.80	$49 14

In order to show the effect of using the quantity of water consumed as a factor in determining the amount to be paid by the several municipalities, the following statements have been prepared, showing the results under different conditions. The assessments of Newton and Hyde Park have been based upon one-sixth of the quantity of water consumed in 1903.

TABLE No. 19.

If each city and town had been assessed for the year 1903 in proportion to the quantity of water used, the amounts paid would have been as follows: —

CITY OR TOWN.	Amount of Assessment, on Basis above given.	DIFFERENCE, COMPARED WITH ACTUAL ASSESSMENT.	
		Less.	More.
Boston,	$1,445,761 76	$65,095 70	-
Somerville,	104,340 45	-	$27,052 02
Newton,	6,315 74	2,937 13	-
Malden,	31,784 22	9,851 09	-
Chelsea,	62,858 40	-	22,980 86
Everett,	42,210 80	-	12,416 65
Quincy,	44,901 52	-	14,664 10
Medford,	29,635 38	-	4,980 52
Hyde Park,	3,045 76	-	295 84
Melrose,	25,150 83	-	7,335 49
Revere,	14,724 26	-	952 62
Watertown,	8,987 78	4,453 05	-
Arlington,	12,033 53	-	483 98
Milton,	5,923 34	3,389 86	-
Winthrop,	12,033 53	-	3,380 09
Stoneham,	8,072 18	-	549 14
Belmont,	3,942 66	1,758 57	-
Lexington,	4,316 38	1,417 39	-
Nahant,	2,522 56	688 52	-
	$1,868,561 08	$95,091 31	$95,091 31

Table No. 20.

If the city of Boston had been assessed in proportion to its valuation, and the remainder of the amount divided among the remaining municipalities in proportion to the quantity of water used by each, the results would have been as follows: —

City or Town.	Amount of Assessment, on Basis above given.	Difference, compared with Actual Assessment.	
		Less.	More.
Boston,	$1,510,857 46	-	-
Somerville,	88,281 25	-	$10,992 82
Newton,	5,340 52	$3,912 35	-
Malden,	26,895 73	14,739 58	-
Chelsea,	53,179 80	-	13,302 26
Everett,	35,705 97	-	5,911 82
Quincy,	37,968 12	-	7,750 70
Medford,	25,071 45	-	416 59
Hyde Park,	2,582 62	167 30	-
Melrose,	21,272 63	-	3,457 29
Revere,	12,458 82	1,312 82	-
Watertown,	7,597 63	5,843 20	-
Arlington,	10,180 24	1,369 31	-
Milton,	5,015 00	9,798 20	-
Winthrop,	10,180 25	-	1,526 81
Stoneham,	6,835 72	687 32	-
Belmont,	3,340 95	2,360 28	-
Lexington,	3,648 58	2,085 19	-
Nahant,	2,128 34	1,082 74	-
	$1,868,561 08	$43,358 29	$43,358 29

Table No. 21.

If the city of Boston had been assessed in proportion to its valuation, and the remainder of the amount divided among the remaining municipalities, one-third in proportion to valuation and two-thirds in proportion to the quantity of water used, the results would have been as follows: —

City or Town.	Amount of Assessment, on Basis above given.	Difference, compared with Actual Assessment.	
		Less.	More.
Boston,	$1,510,857 46	-	-
Somerville,	82,311 18	-	$5,022 75
Newton,	7,923 14	$1,329 73	-
Malden,	30,168 72	11,466 59	-
Chelsea,	45,575 02	-	5,697 48
Everett,	32,347 14	-	2,552 99
Quincy,	34,693 67	-	4,456 25
Medford,	25,436 30	-	781 44
Hyde Park,	2,543 27	206 65	-
Melrose,	20,678 85	-	2,863 51
Revere,	12,998 95	772 69	-
Watertown,	10,030 01	3,410 82	-
Arlington,	10,824 11	725 44	-
Milton,	12,412 32	2,400 88	-
Winthrop,	10,151 63	-	1,498 19
Stoneham,	6,667 60	855 44	-
Belmont,	4,496 33	1,204 90	-
Lexington,	4,821 84	911 93	-
Nahant,	3,623 54	-	412 46
	$1,868,561 08	$23,285 07	$23,285 07

Table No. 22.

If the assessment for 1903 had been divided among all the municipalities, including Boston, one-third in proportion to valuation and two-thirds in proportion to quantity used, the results would have been as follows: —

City or Town.	Amount of Assessment, on Basis above given.	Difference, compared with Actual Assessment.	
		Less.	More.
Boston,	$1,467,474 44	$43,383 02	-
Somerville,	93,016 97	-	$15,728 54
Newton,	8,576 70	676 17	-
Malden,	33,428 56	8,206 75	-
Chelsea,	52,020 74	-	12,143 20
Everett,	36,679 85	-	6,885 70
Quincy,	39,295 84	-	9,058 42
Medford,	28,476 87	-	3,822 01
Hyde Park,	2,858 90	-	108 98
Melrose,	23,263 58	-	5,448 24
Revere,	14,518 72	-	747 08
Watertown,	10,949 77	2,491 06	-
Arlington,	12,052 22	-	502 67
Milton,	13,023 87	1,789 33	-
Winthrop,	11,379 54	-	2,726 10
Stoneham,	7,492 93	30 11	-
Belmont,	4,895 63	805 60	-
Lexington,	5,269 34	464 43	-
Nahant,	3,886 61	-	675 53
	$1,868,561 08	$57,846 47	$57,846 47

Table No. 23.

If the assessment for 1903 had been divided among all the cities and towns, one-half in proportion to valuation and one-half in proportion to quantity used, the results would have been as follows: —

City or Town.	Amount of Assessment, on Basis above given.	Difference, compared with Actual Assessment.	
		Less.	More.
Boston,	$1,478,312 10	$32,545 36	-
Somerville,	87,355 23	-	$10,066 80
Newton,	9,716 52	-	463 65
Malden,	34,250 73	7,384 58	-
Chelsea,	46,601 91	-	6,724 37
Everett,	33,914 38	-	4,120 23
Quincy,	36,511 68	-	6,274 26
Medford,	27,897 62	-	3,242 76
Hyde Park,	2,746 78	3 14	-
Melrose,	22,329 31	-	4,513 97
Revere,	14,406 61	-	634 97
Watertown,	11,940 10	1,500 73	-
Arlington,	12,070 91	-	521 36
Milton,	16,555 45	-	1,742 25
Winthrop,	11,061 88	-	2,408 44
Stoneham,	7,212 65	310 39	-
Belmont,	5,362 77	338 46	-
Lexington,	5,736 48	-	2 71
Nahant,	4,577 97	-	1,366 89
	$1,868,561 08	$42,082 66	$42,082 66

TABLE NO. 24.

If the assessment for 1903 had been divided as follows: Boston, two-thirds in proportion to valuation, one-third in proportion to water used; and other municipalities, one-third in proportion to valuation, two-thirds in proportion to quantity used, the results would have been as follows: —

CITY OR TOWN.	Amount of Assessment, on Basis above given.	DIFFERENCE, COMPARED WITH ACTUAL ASSESSMENT.	
		Less.	More.
Boston,	$1,489,162 83	$21,694 63	-
Somerville,	87,303 33	-	$10,014 90
Newton,	8,403 67	849 20	-
Chelsea,	48,339 13	-	8,461 59
Malden,	31,998 45	9,636 86	-
Everett,	34,308 98	-	4,514 83
Quincy,	36,797 84	-	6,560 42
Medford,	26,979 01	-	2,324 15
Hyde Park,	2,697 52	52 40	-
Melrose,	21,933 01	-	4,117 67
Revere,	13,787 33	-	15 69
Watertown,	10,638 33	2,802 50	-
Arlington,	11,480 59	68 96	-
Milton,	13,165 12	1,648 08	-
Winthrop,	10,767 32	-	2,113 88
Stoneham,	7,071 98	451 06	-
Belmont,	4,769 04	932 19	-
Lexington,	5,114 29	619 48	-
Nahant,	3,843 31	-	632 23
	$1,868,561 08	$38,755 36	$38,755 36

By the provisions of the Act constituting the Metropolitan Water District, the city of Boston was paid for all of its supply works, while those of the other cities and towns were not taken, with the exception of Spot Pond and pumping stations on its shores, which were the property of the cities of Malden, Medford and Melrose. The works of the cities of Quincy and Newton and of the towns of Arlington, Revere, Watertown, Lexington and Hyde Park, also portions of the works supplying water to Malden, Melrose and Medford, were not taken, and are now of little value, excepting those of Newton and Hyde Park, which still furnish those municipalities.

These facts were considered in fixing the proportion of the cost to be paid by Boston and the other municipalities, and the part to be paid by the city of Boston was based upon its valuation in proportion to the valuation of the whole District. The proportion of the valuation of the city of Boston to that of the whole District is larger than the corresponding percentage of its population or of the quantity of water used; for this reason, any change in the present method of assessment of the whole district, by substituting the quantity of water used for population, will decrease the assessment of the city of Boston.

For the year 1903 the percentages of valuation, population and water used in the several municipalities were as follows: —

TABLE NO. 25. — *Showing the Proportion of Valuation, Population and Quantity of Water used for the Year 1903; also, the Proportion of Metropolitan Water Assessment paid by the Several Cities and Towns.*

CITY OR TOWN.	Percentage of Valuation.	Percentage of Estimated Population.	Percentage of Water used.	Percentage paid on Present Basis of Estimate.
Boston,	80.857	66.254	77.373	80.857
Somerville,	3.767	7.505	5.584	4.136
Newton,*	.701	.700	.338	.495
Malden,	1.965	4.098	1.701	2.228
Chelsea,	1.625	3.930	3.364	2.134
Everett,	1.371	3.313	2.259	1.595
Quincy,	1.504	2.977	2.408	1.618
Medford,	1.400	2.503	1.586	1.320
Hyde Park,*	.132	.263	.163	.147
Melrose,	1.043	1.542	1.346	.953
Revere,	.754	1.436	.788	.737
Watertown,	.797	1.201	.481	.719
Arlington,	.648	1.079	.644	.618
Milton,	1.456	.820	.317	.793
Winthrop,	.540	.815	.644	.463
Stoneham,	.539	.706	.432	.403
Belmont,	.364	.533	.211	.305
Lexington,	.383	.396	.231	.307
Nahant,	.354	.247	.135	.172
	100.000	100.000	100.000	100.000

* Percentages for Newton and Hyde Park are based upon one-sixth of the valuation, population and water used.

In view of the conditions under which the present method of apportioning the assessment was established, it does not appear to be equitable to so radically modify the same as to eliminate entirely the factor of valuation. On the other hand, it is very desirable that the assessment shall be divided in such a manner that each city and town shall feel a pecuniary interest in preventing the waste of water. The city of Malden, and the towns of Belmont, Milton and Watertown, have, by the general use of meters, prevented to a great extent the waste of water within their limits; while in most of the other cities and towns in the District very little attention is given to any means of preventing unnecessary use and waste. From a business point of view, it seems proper that those municipalities which adopt measures to prevent waste of water, and thus reduce the expense of constructing and maintaining the Metropolitan Water Works, should receive a direct benefit, and that they should not be obliged to pay for the negligence of others. This can to some extent be accomplished by using both valuation and quantity of water as factors in determining the proportion to be paid; and if each of these factors is given equal value, the results will, as a whole, be an improvement upon the present method.

Reasons for checking Waste.

The quantity of water that will be required in the future to supply cities and towns now furnished with water from the Metropolitan Works is estimated as follows, the figures in the second and third columns being the quantities that will be needed if waste is not checked, and those in the fourth and fifth columns those required if water is sold to all consumers by measurement, and waste of water prevented as far as practicable, assuming, in both cases, an increasing consumption per capita.

Year.	Waste not checked.		Waste prevented.	
	Gallons per Capita.	Million Gallons per Day.	Gallons per Capita.	Million Gallons per Day.
1910,	134	152	80	90
1915,	144	181	85	107
1920,	154	219	90	128
1925,	164	262	95	150
1930,	174	310	100	175

The estimated safe capacity of the Cochituate, Sudbury and Nashua River works is 173,000,000 gallons per day; and, if present conditions are allowed to continue, additional sources of supply will be required by 1913, the construction of which will require several years, so that within five years from the time when the Nashua River works now being built will be finished the construction of new works will be called for.

The sources which were suggested in 1895 by the State Board of Health, in its report on additional water supply, as available for supplementing the supply from the Nashua River, are as follows: —

	Estimated Available Yield (Million Gallons per Day).	Total Available from all Sources (Million Gallons per Day).
Assabet River,	28	201
Upper Ware River,	71	272
Lower Ware and Swift rivers,	200	472

The addition of the Assabet River will be followed almost immediately by works from the Upper Ware River, and within eighteen years the construction of works from the Swift River will become necessary. In order to distribute the increasing quantity of water to the several municipalities, no less than ten lines of large pipes will be required, leading from the terminus of the Weston Aqueduct, and additional main pipes will also be required in different portions of the District. Additional pumping machinery will also be needed.

It is estimated that the cost of the new works required within the next twenty-five years to supply the probable demand for water, if waste is unchecked, will be at least $32,000,000, assuming that the District remains constituted as at present. If other cities and towns are added, as is probable, the time when the additional works will be needed will be shortened.

Not only is the cost of constructing and maintaining the works necessary for supplying water to the Metropolitan District increased by the waste of water, but the cost of the works required to dispose of the water after it has been delivered to the water takers is also increased. The greater part of the water that is wasted runs into the sewers, and is pumped one or more times before being discharged into the ocean. The North Metropolitan Sewerage Works,

when built, about ten years ago, were expected to have a capacity sufficient to meet the demands of the District until 1930; but it has already been found necessary to duplicate some portions of the system, and within a comparatively few years the entire system must be duplicated, if the quantity of sewage to be provided for continues to increase at the present rate. The city of Boston has been obliged to construct new reservoirs and pumping machinery, and new and extensive works are now being constructed to relieve the Boston system of a portion of the sewage now cared for. The total cost of the Metropolitan and Boston main drainage systems has been about $19,000,000; and larger sewers and additional pumping machinery will be required, and increased cost of maintenance will result, if waste of water is allowed to continue to increase. All the available sources of water supply east of the Connecticut River will be required during the next twenty-five years, and an immense sum of money must be expended for the construction of works to bring to the District water which will serve no useful purpose, but will, on the other hand, cause inconvenience and expense to the Metropolitan District, through making necessary additional water mains and sewerage works.

In conclusion, I desire to express my appreciation of the assistance furnished, during the progress of the investigations and the preparation of this report, by the officials in charge of the water departments in the several municipalities of the District.

Table No. 26, appended to this report, gives the daily average number of gallons of water used during each week from June 28, 1903, to January 2, 1904, in the several cities and towns supplied from the Metropolitan Water Works; and Table No. 27 contains statistics relative to the consumption of water, number of services and meters in use, revenue from sale of water, etc., in twenty-one of the large cities of the United States.

Respectfully submitted,

DEXTER BRACKETT,
Engineer, Distribution Department.

New York (Manhattan	
Chicago, Ill.,	
Philadelphia, Pa.,	
Metropolitan Water D	
St. Louis, Mo.,	
Boston,	
Baltimore, Md.,	
Cleveland, O.,	
Buffalo, N. Y.,	
Cincinnati, O.,	
Pittsburg, Pa.,	
Detroit, Mich.,	
Milwaukee, Wis.,	
Newark, N. J.,	
Louisville, Ky.,	
Indianapolis, Ind.,	
Providence, R. I.,	
Toledo, O.,	
Worcester,	
Paterson, N. J.,	
Fall River,	

TABLE No. 27. — *Water Works Statistics of the Large*

CITIES.	Population.	Total Daily Average Consumption (Gallons).	Daily Average Metered Consumption (Gallons).	Number of Services.	Number of Meters.	Miles of Pipe.
ork (Manhattan),	2,091,000	282,000,000	64,246,600	150,000	37,493	897.00
o, Ill.,	2,250,000	358,101,700	41,096,000	324,200	7,075	1,918.80
lphia, Pa.,	1,849,500	313,992,600	16,430,400	255,400	1,510	1,381.00
olitan Water District,	874,200	107,263,000	21,213,500	141,600	13,073	1,457.00
is, Mo.,	650,000	87,000,000	15,149,000	72,005	4,635	709.00
,	–	–	17,521,400	89,337	5,164	727.00
ore, Md.,	525,000	59,647,900	13,226,000	100,151	2,182	634.00
nd, O.,	424,000	69,964,500	19,050,900	56,816	11,099	577.00
, N. Y.,	380,000	116,810,400	16,501,800	67,531	1,375	500.45
nati, O.,	345,400	43,033,000	10,513,670	37,302	3,607	440.00
rg, Pa.,	280,000	63,800,000	4,279,000	36,112	394	362.50
, Mich.,	327,000	51,390,900	14,970,800	63,342	5,847	617.00
kee, Wis.,	308,000	25,010,800	–	45,480	32,721	370.00
k, N. J.,	260,000	26,000,000	–	36,278	13,275	263.00
ille, Ky.,	241,000	16,582,600	–	23,877	1,944	254.00
polis, Ind.,	200,000	15,653,100	–	11,450	650	225.90
nce, R. I.,	198,400	11,563,400	–	22,758	19,216	–
, O.,	140,000	9,823,900	–	12,864	6,292	175.20
ter,	124,300	8,094,800	4,331,000	13,532	13,076	180.90
n, N. J.,	109,000	9,900,000	1,390,400	11,669	3,000	113.90
ver,	108,700	4,365,100	–	7,282	6,973	92.70

Water Works Statistics of the Large Cities of the United States for the Year 190

Daily Average Metered Consumption (Gallons).	Number of Services.	Number of Meters.	Miles of Pipe.	Consumption per Capita (Gallons).	Metered Consumption per Capita (Gallons).	Per Cent. of Consumption metered.	Per Cent. of Services metered.
64,246,000	150,000	37,493	897.00	135.0	30.7	22.80	25.00
41,096,000	324,200	7,075	1,918.80	159.0	18.3	11.50	2.18
16,430,400	255,400	1,510	1,381.00	233.0	12.2	5.23	.59
21,213,500	141,600	13,073	1,457.00	122.7	24.4	19.80	9.24
15,149,000	72,005	4,635	709.00	134.0	23.3	17.41	6.41
17,521,400	89,537	5,164	727.00	-	29.9	-	6.03
13,226,000	100,151	2,182	634.00	114.0	25.2	22.17	2.17
19,050,000	56,816	11,099	577.00	165.0	45.0	27.23	21.11
16,501,800	67,531	1,375	500.45	324.0	46.0	14.12	2.04
10,513,670	37,302	3,607	440.00	124.6	30.4	24.40	9.67
4,279,000	36,112	394	362.50	246.0	16.4	6.71	1.09
14,970,800	63,342	5,847	617.00	157.0	42.7	29.17	9.24
-	45,480	32,721	370.00	81.0	-	-	71.94
-	36,278	13,275	263.00	100.0	-	-	36.60
-	23,877	1,944	254.00	68.8	-	-	8.14
-	11,459	650	225.90	78.0	-	-	5.67
-	22,758	19,216	-	58.0	-	-	84.50
-	12,864	6,292	175.20	70.0	-	-	48.85
4,331,000	13,832	13,076	180.90	65.0	34.8	53.55	94.50
1,390,400	11,669	3,000	113.90	91.0	12.8	14.00	25.70
-	7,282	6,973	92.70	40.1	-	-	-

e Year 1902.

Per Cent. of Services metered.	Total received for Water.	Receipts for Metered Water.	Per Cent. received for Metered Water.	Total received per Million Gallons.	Received for Metered Water per Million Gallons.
25.00	$5,502,894 00	$3,132,316 00	56.00	$54 34	$135 00
2.18	3,164,910 53	1,329,684 69	42.00	24 21	86 00
.59	3,459,095 67	226,684 10	6.56	30 20	38 00
9.24	3,243,634 53	1,286,227 15	39.70	82 85	166 12
6.41	1,748,541 21	760,545 50	43.50	55 00	137 00
6.03	2,306,191 98	1,005,312 26	43.60	-	187 19
2.17	554,530 72	264,283 06	47.60	25 50	55 00
21.11	864,140 11	433,778 81	50.20	33 90	62 00
2.04	682,920 21	135,620 75	19.80	16 00	23 00
9.67	800,970 50	334,505 82	41.76	51 00	88 00
1.09	774,042 64	177,223 00	22.90	33 20	114 00
9.24	398,290 81	136,176 40	34.40	21 20	25 00
71.94	531,853 28	305,112 59	57.50	58 20	-
36.60	695,161 05	381,932 88	54.00	73 20	-
8.14	410,666 17	169,298 87	41.15	67 80	-
5.67	282,231 31	-	-	49 40	-
84.50	605,307 35	512,051 95	84.60	143 50	-
48.85	150,630 19	112,750 37	74.80	42 10	-
94.50	270,088 81	262,500 87	97.20	91 50	196 00
25.70	-	-	-	-	-
-	175,856 95	171,677 36	-	110 20	-

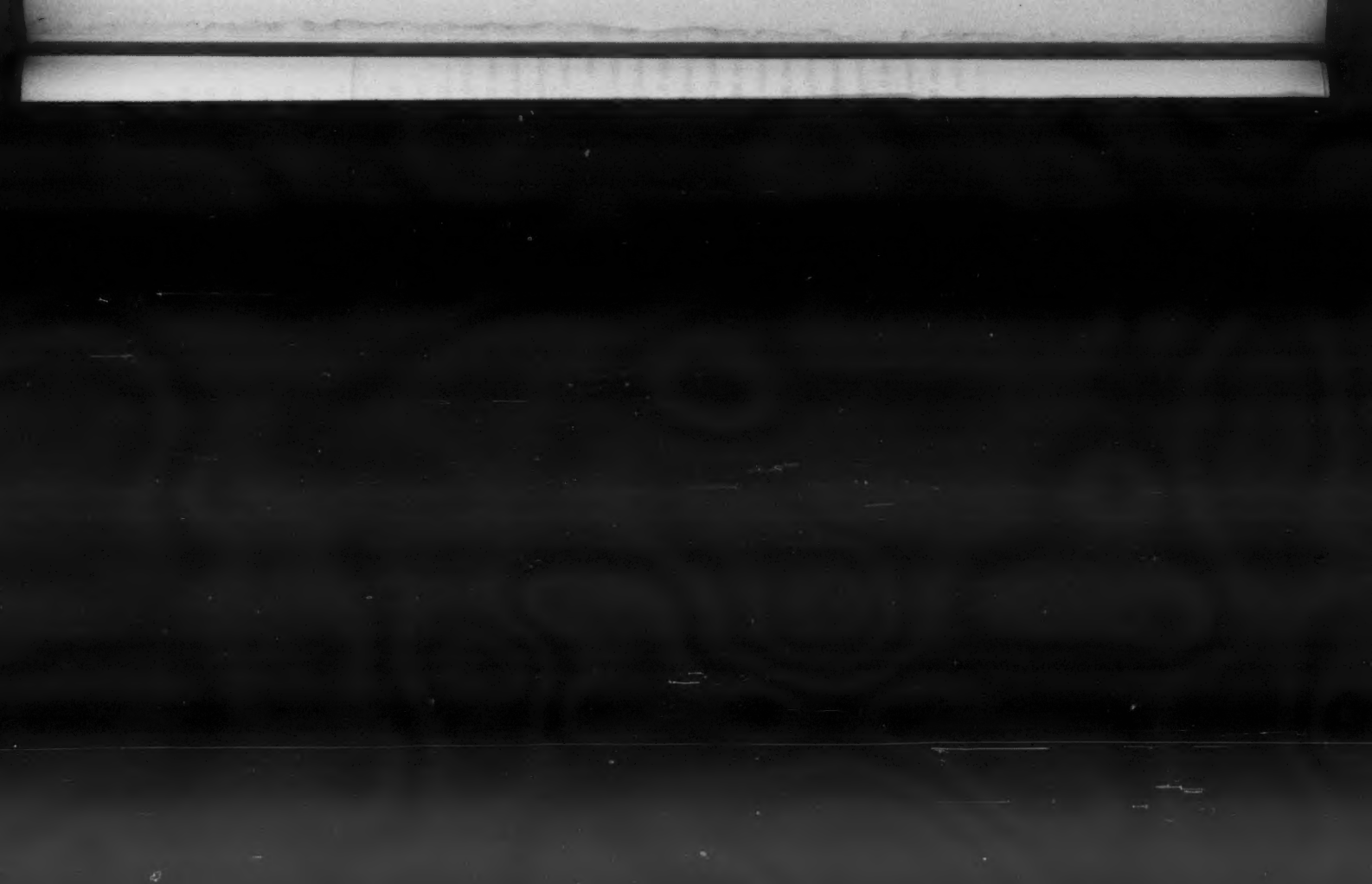


TABLE NO. 26. — *Daily Average Number of Gallons of Water used in the Several Cities and Towns supplied from the Metropolitan Water Works during Each Week from June 28, 1903, to January 2, 1904, as measured by Venturi Meters.*

WEEK ENDING —	Boston.	Somerville.	Malden.	Chelsea.	Everett.	Quincy.	Medford.	Melrose.	Revere.
July 4,	76,482,700	6,086,800	1,853,100	3,326,900	2,206,700	2,612,200	1,892,400	1,396,400	782,100
July 11,	79,510,700	6,478,300	1,912,400	3,507,500	2,212,200	2,964,800	1,810,900	1,525,700	915,000
July 18,	77,770,900	6,208,400	2,002,000	3,394,700	2,290,000	2,992,900	1,946,100	1,570,100	929,100
July 25,	73,421,300	5,871,400	1,731,100	3,155,700	1,986,900	2,274,100	1,574,000	1,378,900	802,000
August 1,	75,708,300	5,588,000	1,910,900	3,252,700	2,168,700	2,454,400	1,467,100	1,440,100	878,700
August 8,	73,795,200	5,143,100	1,613,700	3,226,700	2,113,500	2,256,100	1,535,000	1,400,300	819,400
August 15,	75,639,200	5,548,000	1,735,000	3,173,000	2,115,100	2,437,100	1,485,000	1,413,400	853,600
August 22,	76,778,300	5,458,500	1,829,500	3,192,000	2,235,300	2,471,400	1,624,500	1,433,100	889,400
August 29,	75,117,800	5,284,400	1,868,000	3,213,100	2,283,700	2,434,900	1,667,100	1,386,100	891,600
September 5,	74,989,000	5,224,700	1,737,100	3,093,700	2,216,600	2,328,700	1,554,700	1,319,000	792,600
September 12,	76,318,000	5,551,200	1,884,000	3,078,100	2,243,700	2,361,400	1,719,300	1,408,400	834,900
September 19,	79,178,500	6,075,000	2,070,100	3,271,300	2,395,000	2,489,100	1,899,600	1,535,100	880,100
September 26,	77,764,900	5,522,000	1,954,000	3,240,800	2,204,400	2,410,900	1,777,500	1,448,900	783,000
October 3,	76,847,200	5,691,200	1,841,600	3,277,200	2,204,700	2,324,700	1,764,700	1,485,600	735,900
October 10,	76,597,700	5,668,900	1,751,400	3,235,400	2,130,700	2,260,600	1,680,300	1,440,400	706,700
October 17,	77,009,800	5,303,900	1,688,900	3,190,400	2,177,900	2,229,000	1,618,400	1,395,000	693,000
October 24,	76,949,600	5,312,400	1,800,800	3,196,100	2,244,800	2,267,300	1,618,500	1,407,400	698,700
October 31,	76,689,600	5,298,400	1,687,400	3,121,700	2,285,100	2,314,400	1,622,700	1,385,100	707,400
November 7,	77,502,200	5,320,800	1,692,500	3,095,000	2,333,400	2,300,300	1,620,100	1,400,000	700,000
November 14,	77,384,500	5,284,000	1,648,600	3,157,100	2,302,300	2,202,100	1,585,100	1,344,300	686,400
November 21,	75,903,100	5,283,700	1,620,600	3,141,400	2,330,000	2,233,100	1,575,500	1,315,900	673,400
November 28,	76,904,000	5,108,900	1,535,500	3,337,400	2,379,700	2,239,600	1,597,000	1,312,600	685,500
December 5,	81,096,600	5,515,600	1,567,700	3,714,800	2,553,600	2,373,700	1,588,400	1,314,900	767,700
December 12,	79,365,400	5,350,700	1,589,900	3,495,800	2,461,000	2,346,900	1,549,900	1,304,700	711,800
December 19,	86,711,200	5,942,300	1,593,500	4,054,900	2,641,600	2,455,400	1,651,900	1,325,300	851,200
December 26,	86,086,000	6,099,200	1,768,000	4,546,500	2,713,100	2,692,700	1,745,800	1,279,000	853,500
January 2,	94,639,400	6,487,300	1,750,800	5,080,300	2,852,000	2,483,400	1,773,200	1,301,000	961,000
Average gallons per day,	78,228,200	5,600,300	1,764,400	3,398,900	2,306,700	2,415,200	1,653,500	1,395,100	795,700

TABLE No. 26 — *Concluded.*

WEEK ENDING —	Watertown.	Arlington.	Milton.	Winthrop.	Stoneham.	Belmont.	Lexington.	Nahant.	Swampscott.	Total.
July 4,	528,700	722,700	502,900	683,000	377,100	165,200	292,000	335,000	604,900	100,350,800
July 11,	611,200	854,200	585,300	817,700	509,700	214,100	352,300	379,900	726,700	105,666,600
July 18,	636,700	941,200	575,500	814,000	493,600	262,900	253,000	309,600	786,100	104,066,800
July 25,	506,700	737,000	270,900	589,600	497,100	170,400	205,400	215,600	690,000	95,578,100
August 1,	587,300	695,400	366,700	767,700	496,800	213,300	243,000	256,600	710,900	99,206,400
August 8,	522,700	670,000	334,700	768,900	512,000	215,900	261,300	232,200	696,500	96,117,300
August 15,	581,100	630,000	354,700	750,000	508,000	244,300	269,000	213,200	708,900	98,658,600
August 22,	559,200	630,200	344,800	764,000	521,000	235,100	278,400	289,000	726,400	100,260,100
August 29,	544,200	651,900	317,000	775,600	499,000	228,800	312,600	234,300	745,000	98,455,100
September 5,	496,400	528,900	292,100	665,100	447,900	208,700	274,900	150,600	658,400	96,994,100
September 12,	554,300	582,700	377,000	690,400	441,900	188,100	321,900	180,900	659,400	99,395,600
September 19,	594,100	624,400	400,700	762,300	491,900	308,000	327,600	238,500	633,400	104,174,700
September 26,	579,700	634,700	378,000	683,100	461,700	274,600	309,100	204,700	685,900	101,117,900
October 3,	558,400	617,200	356,100	639,300	438,000	281,100	296,100	167,700	508,000	100,034,700
October 10,	577,700	553,200	312,500	597,300	428,600	254,700	259,600	103,100	425,900	98,984,700
October 17,	529,000	554,400	301,400	594,000	416,300	236,400	209,700	91,500	456,900	98,695,900
October 24,	504,100	556,700	320,400	603,900	446,700	243,900	223,900	51,900	450,100	98,897,200
October 31,	478,400	525,900	330,000	600,000	476,600	220,600	215,900	62,900	473,500	98,495,600
November 7,	522,400	543,300	349,400	580,300	449,400	229,400	188,600	40,000	426,400	99,293,500
November 14,	497,700	525,900	325,000	575,100	442,400	226,100	186,000	40,000	389,600	98,732,200
November 21,	490,600	539,400	324,400	536,300	449,900	226,700	169,300	44,600	302,600	97,160,500
November 28,	478,600	519,200	316,900	557,600	434,700	222,400	178,900	40,000	293,300	98,141,800
December 5,	486,900	522,700	313,800	594,300	460,900	225,700	187,700	48,100	340,700	103,673,800
December 12,	479,000	518,300	268,600	584,400	484,800	219,100	176,700	56,900	327,000	101,290,900
December 19,	493,400	542,900	265,400	641,300	481,600	207,700	189,700	42,500	313,100	110,402,900
December 26,	438,000	572,500	262,400	657,200	459,700	205,900	194,800	41,100	362,200	110,977,600
January 2,	515,600	709,400	261,200	741,800	491,600	222,700	176,800	53,300	355,500	120,586,300
Average gallons per day,	531,600	619,000	325,300	667,900	467,400	227,800	242,700	157,500	527,300	101,324,500

MOSQUITOES AND SUGGESTIONS FOR THEIR EXTERMINATION.*

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[*Presented January* 13, 1904.]

The statement has been frequently made of late that there is no more reason why we should suffer from mosquitoes than there is that we should allow rats and mice to continually annoy us, and this statement is in a measure true. Rats and mice are to a great extent effectively held in check, for we have become accustomed to them and their habits, and we know how to deal with them. Were it not for the fact that a constant warfare is being waged against them, they would soon overrun our houses and make life unbearable.

In order to fight the mosquitoes successfully it is important that every one should take an interest in the popular uprising against this insect pest. And now that it is known that, besides being a nuisance, mosquitoes may be a menace to the health of the community, it is equally necessary that every one should become familiar with all that pertains to their life history, so that the war against them may be successfully and intelligently carried on. Notwithstanding all that has been written on the subject of mosquitoes during the last year or two, the majority of people still know but little about them.

It is the purpose of this article to state, in as simple a manner as possible, the facts that are now known regarding mosquitoes and how to deal with these pests, and it is hoped that this information may help to secure a more general coöperation in the work of mosquito extermination.

Few people realize that there are a great many different kinds

* Illustrated with photographs from life by the author. The article and the photographs are copyrighted.

of mosquitoes. Some 300 species have already been described, and here in the United States we have about 50 species, belonging to nine different genera. The most common of these genera in the northern states are *Anopheles*, the malarial, and *Culex*, the ordinary, mosquito. Of the former there are two species and of the latter at least fifteen.

Only these two genera and the methods for their extermination will be especially considered, and as these methods may also be successfully applied to the other kinds of mosquitoes, no detailed description of the others need be given.

It is commonly and quite naturally thought that mosquitoes breed in wet grass, as they are often seen to rise from it in clouds when disturbed, particularly in the early morning and evening. They have not bred there, however, but have merely sought the shelter of the grass where they can be protected from the wind. The moisture of the dew upon the grass also furnishes an attraction for them and they always prefer damp rather than dry places.

Another popular theory is that mosquitoes will breed *only* in foul or stagnant water. This is also a mistaken idea, though they often do breed in such water, not because it is impure or stagnant, however, but because these places are usually quiet, and here the female can deposit her eggs undisturbed.

It is commonly supposed that mosquitoes do not breed in salt water, but the recent "Mosquito Investigations" of Prof. John B. Smith, of New Jersey, which were published in the New Jersey Agricultural College Experiment Station Report of November, 1902, show that the larvæ of *Culex sollicitans*, the "Salt marsh mosquito," not only prefer salt or brackish water, but are seldom found in pools where the water is strictly fresh, and, contrary to the usual custom, this mosquito lays its eggs upon the soil of marsh or meadow land. There the eggs remain until the advent of an unusually high tide. Then after a few hours when the water has covered them, the infant larvæ make their appearance.

It is very generally believed that mosquitoes bite but once and then die. This is sometimes so; but, unless they are killed in the act of biting, they usually live to bite again. The female mosquito (for it is only the female that attacks human beings) bites many times. It is owing to this fact that *Anopheles* is able to

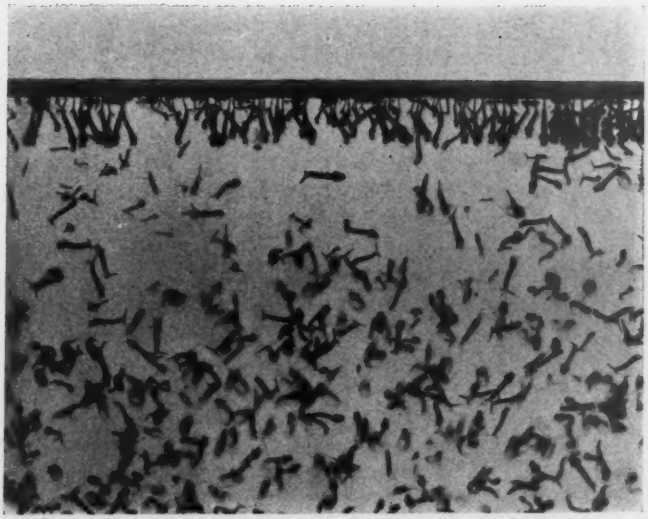

Fig. 1. — Mosquito "wigglers" — larvæ and pupæ — in the water. Life size.

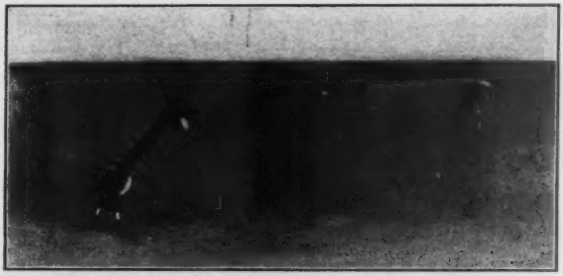

Fig. 2. — Mosquito "wigglers" (larvæ) in the water. *Anopheles* larva to the right. *Culex* larva to the left. Three times as large as life.

Fig 3. — A pupa, the third stage in a mosquito's life. Three times as large as life.

convey the germs of malarial fever from person to person. When biting any one who is afflicted with malaria, the insect draws in with the blood the germs of the disease, which it afterwards carries on into the blood of another victim. The vast majority of mosquitoes never get human blood for food. In its absence they live upon the blood of birds and other animals, and when these are not to be found, upon the juices of young and tender plants.

It is not known just how long mosquitoes can live, but their average life is much longer than is ordinarily supposed. Thousands of them live through winter, hibernating or asleep in dark places in barns or house cellars. In sparsely settled localities, where they cannot find such places for shelter, they live through the winter in hollow trees, in caves and holes under upturned trees; and, even though the temperature may fall far below freezing, they are not winter-killed, but on the approach of warm weather become active again. Mosquitoes are frequently seen flying about in the woods before the snow has wholly left the ground.

Mosquitoes cannot develop or come to maturity without water in which to live during the first weeks of their "wiggler" existence.

A mosquito's life is divided into four stages — the egg, the larva, the pupa, and the adult insect. In the larval and pupal stages, mosquitoes are more commonly known as "wigglers" (see Fig. 1, Plate I). Both *Anopheles*, the malarial, and *Culex*, the common, mosquito larvæ are present in this picture. Mosquito "wigglers" may frequently be found in rain-water barrels in as large numbers as are seen in this photograph. The female mosquito lays from one hundred and fifty to four hundred eggs upon the surface of some quiet water, and in a day or two these eggs develop into the larval or second stage (see Fig. 2, Plate I).

It will be noticed that *Culex* hangs with its head down, and from its tail upward to the surface of the water extends a small tube. Through this tube it breathes. *Anopheles* rests just beneath and parallel to the surface of the water, and its breathing tube is much shorter than that of *Culex*. These resting positions are quite different, and each is characteristic of its kind. Except

when disturbed, *Anopheles* is generally to be found at the surface, breathing and feeding in this position. *Culex*, on the other hand, comes to the surface only occasionally to breathe. It stays below the water for the greater part of the time, and is often found feeding from the bottom.

At the end of a few days the larvæ change into the pupal or third stage (see Fig. 3, Plate I). To the left is seen the larval skin out of which this pupa has just come. The difference between *Culex* and *Anopheles* in this, the final stage of "wiggler" existence, is very slight. Both now live at the surface of the water, and they breathe through two funnel-shaped tubes situated one on each side of the thorax, or "head." Unless disturbed they remain motionless in this position at the surface until the time comes when, as adult mosquitoes, they leave the water (see Fig. 1, Plate II). This is the critical period of a mosquito's life; for, should the surface of the water be disturbed at this time, the insect would be upset and drowned. It takes about seven minutes from the time when the skin along the back of the pupa begins to split until the full-grown mosquito comes forth, and in a few minutes is ready to fly away. A mosquito never grows any larger after this change.

The length of time required to pass from the egg to the adult insect varies from ten days to three weeks, according to the temperature. Warm weather hastens their development, while low temperature checks it. The "wigglers" of some species of mosquitoes live through the coldest weather of our northern winters unharmed, ready, when the first warm days of spring have come, to complete their natural changes.

Mosquitoes' eggs are so very small that ordinarily they remain unnoticed, but nearly every one who lives in the country is familiar with the little "wigglers" that are often seen squirming up and down in rain-water barrels. Few people know that these little fellows are connected in any way with mosquitoes, but it is a very easy matter to prove that they are. Let any one who doubts this fact dip up a few in a glass jar or tumbler and place them in the house, where they can be frequently looked at. Seeing is believing; and after a full-grown mosquito has once been seen to come forth from a pupa (which is the last stage of the

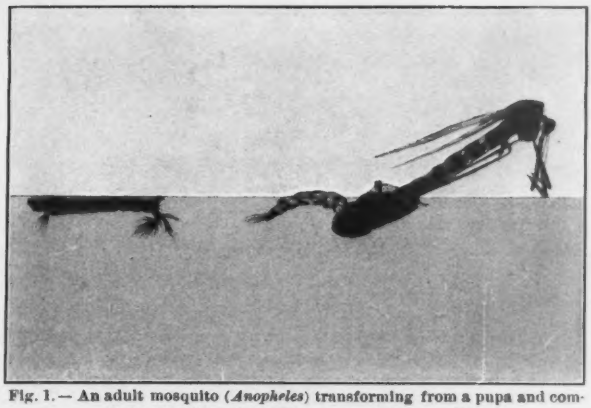

Fig. 1. — An adult mosquito (*Anopheles*) transforming from a pupa and coming out of the water. Three times as large as life.

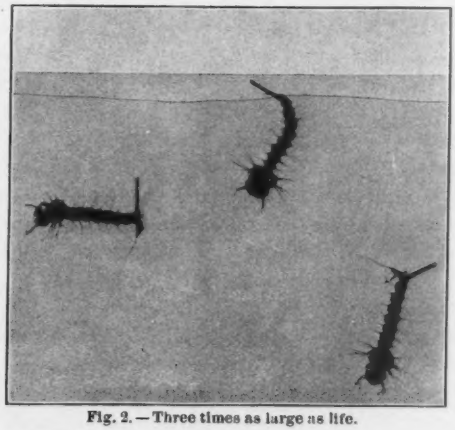

Fig. 2. — Three times as large as life.

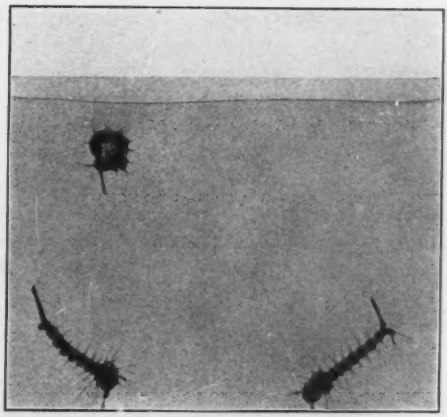

Fig. 3. — Three times as large as life.

"wiggler"), there can no longer be any question as to what these "wigglers" really are.

Most of the mosquitoes that annoy us are bred near by, often, though unknown to us, in our own dooryards. Any water that is accessible to mosquitoes and whose surface is undisturbed by winds or rapid currents furnishes a breeding-place for them, and "wigglers" may often be found in water standing in old tin cans or bottles, in rain-water barrels, in pools in the rocks, in roof or street gutters that are not properly drained, in cesspools or in catch-basins, in fact, in any place that will hold water for a week or two, no matter how small the quantity, even if only a few teaspoonfuls.

Since we know that without water mosquitoes in their first stages cannot exist, it naturally follows that all standing water should be done away with, or treated in such a manner that "wigglers" cannot live in it nor mosquitoes get to it to lay their eggs. To this end all cans, bottles, and every discarded utensil that will hold water should be removed. All stagnant pools, where it is possible to do so, should be drained or filled up. Cisterns, rain-water barrels, and cesspools should be screened or otherwise covered to prevent the adult insects from having access to them. Where it is not practicable to fill, drain, or screen the places that are suitable for mosquitoes to breed in, the surface of the water may be covered with kerosene oil. This oil, when spread over the water, prevents the "wigglers" from getting air when they come to the surface to breathe, and so kills them (see Figs. 2 and 3, Plate II).

In Fig. 2, Plate II, a "wiggler" is seen trying to get air, vainly thrusting its breathing tube up into the film of kerosene.

In Fig. 3, Plate II, the upper "wiggler" is grasping its breathing tube in its mouth, apparently trying to pull off the small particles of kerosene with which the tube has been clogged. The "wigglers" upon the bottom have been suffocated and have given up the fight.

An ounce (two tablespoonfuls) of kerosene will spread over fifteen square feet of water surface, forming a film thick enough to kill all the "wigglers" that are beneath it. Kerosene of a cheap quality, known as high-test light fuel oil, is preferable for

this purpose. It can usually be bought at eight cents a gallon. If oil of this quality is not available, ordinary kerosene will answer the purpose. It should be applied as often as once in two weeks, for by that time the previous application will have evaporated. A sufficient quantity should be used, in the proportions named. to cover completely any place that may need treatment.

Any one who is ill with malaria or yellow fever should be carefully protected from mosquitoes, for, should a person be bitten by an *Anopheles*, the malarial mosquito, or *Stegomyia fasciata*, the yellow fever mosquito, at this time, there would be great danger that the insects might fly away and bite some one else and thus spread these diseases. Screens for both doors and windows form the best protection against mosquitoes at all times; but it often happens that the insects get into our houses, even though they are thoroughly screened, generally through some door or window that has been left open by mistake, or they may gain an entrance by coming down an unused chimney if the flue is allowed to remain open during the summer time. A house or a room may be cleared of mosquitoes by burning pyrethrum powder and allowing the smoke, which is not at all offensive to most people, thoroughly to fill the room that is under treatment. This smoke kills or so stupefies the insects that they will not bite. Pyrethrum powder is a preparation of the plant *Pyrethrum roseum*, and is sometimes sold as Persian Insect Powder or Dalmation Powder; it can be bought at any drug store for about thirty-five cents a pound. It is a very fine, light powder, and an ounce of it will go a long way, making a large volume of smoke. A pyrethrum smudge or smoke may be started by covering a live coal, taken from the kitchen stove, with the powder, first placing the coal upon a small shovel, so that it may be moved about conveniently without danger of setting anything on fire. The pyrethrum will quickly begin to smoulder and give off a dense smoke. All that is now necessary is to add from time to time a pinch of the powder as occasion requires, merely keeping the smouldering ashes covered so that they will give off a smoke. People are frequently annoyed and sometimes driven into their houses on summer evenings by the persistent attacks of mosquitoes. On such occasions, pyrethrum powder can often be

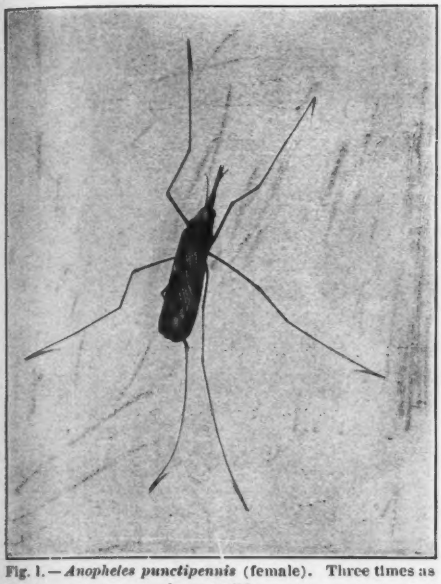

Fig. 1.—*Anopheles punctipennis* (female). Three times as large as life.

Fig. 3.—Profile of *Anopheles punctipennis* (female). Three times as large as life. Showing the characteristic resting position of this mosquito.

Fig. 4.—Profile of a *Culex* mosquito (female). Three times as large as life.

Fig. 2.—*Anopheles maculipennis* (female). Three times larger than life.

Fig 5.—Profile of a male *Culex* mosquito. Three times as large as life.

used to advantage; and the smoke from a small quantity of the powder kept smouldering on the piazza will drive away most, if not all, of the pests, thus making it possible to enjoy an evening out of doors in comfort, when otherwise life would be unbearable except behind the protection of screens.

The *Anopheles*, or malarial mosquitoes, though not very common (see Figs. 1, 2, and 3, Plate III), are breeding quite abundantly in many parts of this country; and by referring to the accompanying photographs, particularly the ones in profile, it will be seen that there is quite a difference between the malarial and the common, or *Culex*, mosquitoes.

Anopheles may easily be distinguished from the common or *Culex* family of mosquitoes by the spots upon their wings, and also by the position which they take when at rest (see Fig. 3, Plate III).

Notice the angle at which the insect shown in Fig. 3 stands out from the wall. Compare this with Fig. 4, Plate III. It will also be seen that the proboscis, or "stinger," and the body of *Anopheles* form a straight line, while the *Culex* is rather humpbacked. The other *Anopheles maculipennis* does not stand out from the wall at quite such an angle as does *punctipennis;* but like the latter its proboscis and body form a straight line, and the angle formed by the insect when at rest is much greater than that of the *Culex*.

Notice how different is the resting position of the mosquito in Fig. 4 from that of *Anopheles* in Fig. 3, Plate III.

The male mosquito (see Fig. 5, Plate III) never bites. He may be easily distinguished by his large and feathered antennæ and palpi, which are very much more prominent than those of the female.

There is another mosquito, *Stegomyia fasciata*, which in form and habits closely resembles *Culex*, in which genus, until quite recently, it was classed. *Stegomyia fasciata* is the yellow fever mosquito, and it inhabits only the warmer portions of this country. It is common in most of our southern states, and is seldom seen north of the Carolinas. It is easily distinguished from other mosquitoes by the conspicuous silvery white stripes upon its thorax and abdomen, and by the white bands upon its legs.

Fortunately for mankind, nature herself provides many energetic workers which are constantly doing their part towards hold-

ing in check these insect pests. Foremost among these natural enemies are many of the insectivorous birds, which daily destroy many thousands of mosquitoes. The swallows, the fly-catchers, the night-hawks, and the whip-poor-wills, all are insect exterminators, whose good work in this connection is seldom taken into account. The bat is also an efficient mosquito hunter; so, too, are the dragon flies which frequent the shores of ponds and pools where mosquitoes breed.

Besides these enemies of the adult mosquito, which may properly be called their "foes of the air," mosquitoes have other adversaries which destroy them in their early stages. These may be termed their "foes of the water."

It often happens that we can find no "wigglers" in small ponds in which we would naturally expect to find mosquitoes breeding. In such ponds the presence of fish may account for the absence of mosquitoes. Their larvæ furnish food for many species of our smaller fishes, and by them myriads of mosquitoes are annually destroyed. Goldfish are particularly fond of mosquito "wigglers," and the pair of fish in the illustration (see Fig. 1, Plate IV) were seen to eat ninety-eight "wigglers" in four minutes. Goldfish will live and multiply in almost any small and shallow pond in this vicinity, where the water is warm. They are perfectly hardy and will thrive just as well and perhaps better in stagnant water than they will in flowing streams.

The "top minnow," the roach, the sunfish or "pumpkin seed," and even the sluggish hornpout, all play an important part in reducing the numbers of mosquito "wigglers." Besides the fishes, there are other "foes of the water" that prey upon mosquito larvæ. Many of the predatory water bugs feed upon them. Prof. J. B. Smith, in the report previously referred to, says that "among these predatory insects which abound in shallow, permanent bodies of water wherever there is vegetation, the water boatman (*Corisa* and *Notonecta*), the water striders or 'skate bugs' (*Hydrobatidæ*) and the water scorpions (*Nepidæ belostomatidæ*) deserve mention." He also speaks of the "water tiger," the larva of the large water beetle (*Dytiscus*), and tells of its ability to clear *Culex* larvæ from pools of water.

In this connection a brief description of a newly discovered

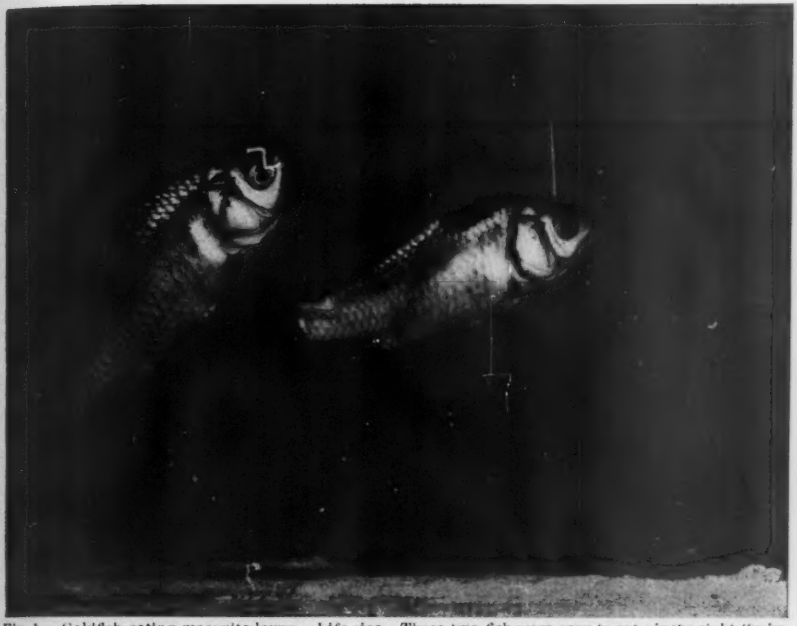

Fig. 1. — Goldfish eating mosquito larvæ. Life size. These two fish were seen to eat ninety-eight "wigglers" in four minutes. They always fed upon mosquito larvæ when they could get them in preference to prepared goldfish food.

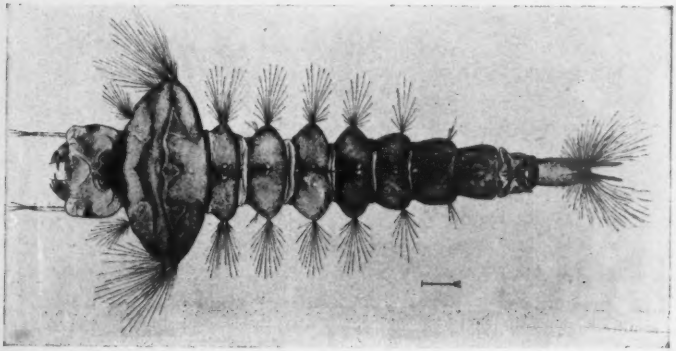

Fig. 2. — Larva *Eucorethra underwoodi*. Dorsal view. Original drawing. Six times as large as life.

mosquito,* to which has been given the name *Eucorethra underwoodi*, should be of interest, since it has been found that their larvæ devour the wigglers of other mosquitoes, and unlike other mosquitoes, the adult female insect does not bite. As the proboscis of this insect is so formed that it cannot puncture the skin, it should not perhaps be called a true mosquito, though it has been classed as one, since it belongs to the family *Culicidæ*.

The larvæ of this insect were found by the author on January 27, 1903, in the Maine woods in the eastern section of Penobscot County, and were discovered in a spring of water from which a crew of lumbermen were getting their water supply. A few days later, other larvæ of the same species were found in a similar spring about eight miles distant, though in this case, as the spring was not in use, its surface was covered with a coating of ice an inch thick. The temperature of the water at the bottom (it was about two feet deep) was 42° F.

At first sight this larva would be taken for an *Anopheles* of extraordinary size, as it is of the same general shape, and when the water was cleared of ice, it lay just beneath and parallel to the surface, breathing through a short respiratory siphon, as is characteristic of the larvæ of *Anopheles*. In this spring a barrel had been sunk, and in the fifty gallons, or thereabouts, of water which it contained, there were twenty-five larvæ. They were all of about the same size — 12 to 14 mm. long — and almost black in color. All were secured and taken into camp for further investigation.

Close observation of the larvæ showed that besides being much larger (12 to 14 mm. long instead of 5 to 7 mm.), they differed in many other particulars from the larvæ of *Anopheles* (see Fig. 2, Plate IV). In proportion to the rest of its body, its head is larger than the head of *Anopheles*. It does not turn its head upside down when feeding as does *Anopheles*. Its mandibles are strikingly large and powerful, and are prominently toothed. It lacks the frontal tufts or brushes which are conspicuously present in *Anopheles*, and its antennæ, which extend directly forward parallel with the sides of the head, are much longer and more slender, and are tipped

* Under the title "A New Mosquito" a description of this mosquito appeared in *Science*, August 7, New Series, Vol. XVIII, No. 449.

each with three hairs of equal size. The thorax is broadly elliptical, and is much wider in comparison with its abdominal segments than is the thorax of *Anopheles*. The sides of the thorax and the abdominal segments bear fan-shaped tufts of hairs, not plumosed as in *Anopheles*. The tufts on the last segments, both dorsal and ventral (see Fig. 1, Plate V), are more profuse in *Eucorethra* than in *Anopheles*, especially the ventral tuft, which in *Eucorethra* occupies nearly the whole segment. Only two anal papillæ are present, while *Anopheles* has four.

A few days before the author returned to Boston, several larvæ died and three changed to pupæ. The pupa resembles that of *Culex* (see Fig. 2, Plate V), rather than of *Anopheles*, and its respiratory siphons are of the same shape as those of *Culex*. When stretched out at full length, the pupa measures 10 mm.

On reaching home, the new wigglers, eighteen in number, were put into a quart jar which was placed near a window where it would receive the sunlight for two hours each morning. The temperature of the water now averaged about 70° F., and with this change the larvæ developed a new trait,— they began to eat each other up. The act was witnessed on several occasions. The larva would grasp its adversary just forward of the respiratory siphon with its powerful mouth parts, and working the tail in first, it would gradually swallow its victim, shaking it now and then as a terrier would shake a rat.

After losing many of the insects in this way, those that remained were separated, and each individual was placed in a small bottle by itself. Eventually, I succeeded in rearing a number of males and females. The pupal stage of this insect varies from five days and nine hours to six days and ten hours. The adult (see Fig. 3, Plate V), resembles *Anopheles* in having maculated or spotted wings, but is much larger and measures eleven millimeters in length. Its mouth parts, however, are not adapted for biting. A full description of the imago is soon to be recorded by Mr. D. W. Coquillett, of the National Museum, by whom the name above mentioned was given.

During a visit to Maine in June, a large number of larvæ of *Eucorethra* were taken from the spring where the barrel had been sunk. It was noticeable that larvæ of other kinds of mosquitoes

Fig. 1. — Last segment of larva profile. Original drawing. Six times as large as life.

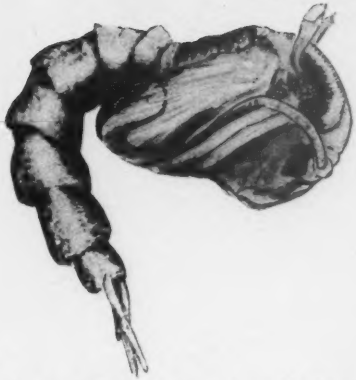

Fig. 2. — Pupa *Eucorethra underwoodi*. Original drawing. About eight times as large as life.

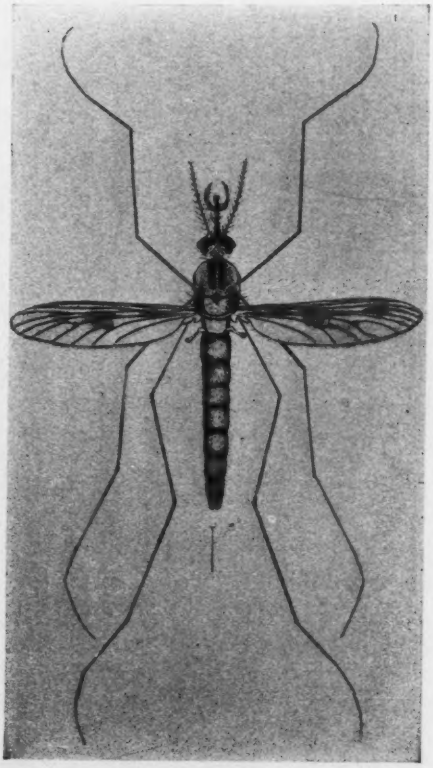

Fig. 3. — *Eucorethra underwoodi*. Coquillett MS. Original drawing. Four times as large as life.

were absent, although the adults were very numerous in the immediate vicinity.

The absence of other mosquito larvæ was accounted for when later it was discovered that the larvæ of *Eucorethra* fed upon the larvæ of other mosquitoes, eating them apparently with great relish. On several occasions fourteen *Eucorethra* larvæ ate, during the night, sixty *Culex* larvæ out of the seventy that had been placed in the water with them. When eating the larvæ of mosquitoes smaller than themselves, the victim is caught, shaken violently a few times, and swallowed in a few seconds in very much the same way that a pickerel would catch and swallow a smaller fish.

As yet no experiments have been made to see if this new species will devour the larvæ of *Anopheles* as readily as they will those of *Culex*. Whether or not this species will thrive in the climate of southern New England is as yet uncertain, but experiments are now being carried on to determine this point.

Although myriads of mosquitoes are destroyed by the natural enemies which have been mentioned, *man should* be the most destructive foe of these insects. There is no doubt that the mosquito pest may be very largely abated by the employment of scientific methods for causing its destruction in the early stages of its development.

While it is the duty of boards of health to recognize mosquitoes as active agencies for the dissemination of certain diseases and to take such measures as are possible for their extermination, the work can never be effectively done until the people of each community are fully informed in regard to the life history of the mosquito, so that all may coöperate intelligently to secure its destruction.

DISCUSSION.

Mr. Freeman C. Coffin.* I should like to ask a question. We understand that in the economy of nature there is a use for everything, and I should like to ask the speaker of what use are mosquitoes.

* Civil Engineer, Boston, Mass.

MR. UNDERWOOD. I think it is generally understood that there is a use for everything in the economy of Nature, but the only thing I can see that mosquitoes are of use for is as food for ducks and fish, and as ducks and fish are eaten by us, perhaps in a round-about way mosquitoes may be of some use to us; but I think I would risk losing my fish and ducks in order to be freed from the mosquitoes. I don't think they are of any use.

MR. ROBERT J. THOMAS.* I should like to ask if tobacco smoke will drive mosquitoes away?

MR. UNDERWOOD. Tobacco and cigar smoke does have a very good effect. I think if you were to burn tobacco on the piazza in the same way that you do pyrethrum powder it would possibly be more effective in driving the mosquitoes away. All of us who smoke know that mosquitoes keep away from us if we are smoking, but tobacco smoke is not pleasant to some people. When collecting mosquitoes in the woods, I have a little glass jar with me and I put it over a mosquito when it is biting, and then puff a little tobacco smoke into the jar and in a very few minutes the mosquito is dead.

MR. FRANK L. FULLER.† I would like to inquire as to the quantity of kerosene oil needed per acre.

MR. UNDERWOOD. I am not a very good mathematician. An ounce of oil will cover 15 square feet, and from that you can figure how much it will take for an acre. In the photograph I showed you of course the oil was very much thicker than would have to be used, but, as I say, an ounce to 15 square feet, although it will not make a very deep film, will be enough. You know that if you put a few drops of oil on water you will see a blue film, and wherever you see that film you won't see any mosquitoes. I am told that in the oil fields of Pennsylvania years ago, before oil was discovered, there were a great many mosquitoes, and it is said that now around the oil fields they never have any. The pools of water are all covered with a film of oil and the mosquitoes cannot breed in them. I am told this by people who have lived there, and while it may not be true it seems very natural to me that it should be so.

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* Superintendent of Water Works, Lowell, Mass.

† Civil Engineer, Boston, Mass.

MR. HARRISON P. EDDY.* In connection with some experiments with sewage last summer I had a tank about 10 feet long, 3 feet wide, and 6 feet deep, which was filled with sewage. This was agitated violently about half an hour at a time four times a day, and the surface of the water was entirely covered with a film of oil, quite a thick film, so thick that if you dipped a pencil into it the pencil showed the traces of the oil. Mosquitoes bred there very rapidly, and did not seem to be affected either by the oil or by the agitation. Now, I would like to ask if the two remedies which Mr. Underwood has told us of are always unfailing?

MR. UNDERWOOD. How did the water get into the tank? Did it come from the sewer?

MR. EDDY. Right from the sewer. It was an experimental tank and was connected with the main trunk sewer.

MR. UNDERWOOD. And the oil was put on to keep the mosquitoes away?

MR. EDDY. No; the oil was a natural oil which came to the surface of the sewage. The tank was exposed to the sun, and probably a temperature of about 70 degrees was maintained during the daytime.

MR. UNDERWOOD. You might account for the mosquitoes coming there. The agitation itself would not prevent them. In the hour or two which intervened between one agitation and another a good many hundred mosquitoes could deposit their eggs, and the agitation afterwards would not hurt the eggs or the wigglers. If the agitation occurred about the time the pupæ were going to split and the adults come out, it would kill the mosquitoes. The oil was not kerosene, and it depends upon the kind of oil. Kerosene oil and one other oil, I don't at the moment remember what it is, are mosquito exterminators, but I think a large majority of oils would not have any effect in killing them.

MR. S. A. AGNEW. How often is it necessary to treat the pools with oil?

MR. UNDERWOOD. They should be treated on an average of every two weeks. The average length of time from the egg to the adult, as I said, in very warm weather is about ten days, and it is the rule to treat the pools about every two weeks; that has

* Superintendent of Sewers, Worcester, Mass.

been found to be effective. I would suggest to Mr. Eddy that if his experiments are carried on another summer, if he will put kerosene oil upon the tank I think he will find that he will not have any mosquitoes there, unless the agitation should be so violent as to carry the oil down into the water or cause it to evaporate or something of that kind. It seems to me that if kerosene oil were put on it would not be possible for mosquitoes to breed there.

MR. EDDY. It occurred to me whether the agitation wouldn't give them sufficient oxygen.

MR. UNDERWOOD. I think it might well be so.

MR. EDDY. The water was violently agitated for periods of half an hour, compressed air being used under a pressure of five or six pounds.

MR. UNDERWOOD. I think that might have a very decided effect; perhaps, would give them enough oxygen even if kerosene were used upon the surface.

MR. F. W. DEAN.* Mr. Underwood spoke about the natural enemies of mosquitoes, and I would ask him if he is aware of the effect of the plant called sun-dew as a destroyer of mosquitoes?

MR. UNDERWOOD. I have heard about it but I am not familiar with it.

MR. DEAN. I don't know whether the plant grows about here or not, but in 1881 and 1882 I was on the island of Campobello off Eastport, Maine, and Professor Shaler was concerned in the survey also. He discovered that the sun-dew grew in Campobello in considerable quantities, and the Professor being quite original, as you know, and bringing mathematics and other sciences to his aid as may seem desirable, made an estimate of the number of patches of sun-dew there were on the island and the number of dead mosquitoes he found on the plants, and he figured up that in a year 365 000 000 mosquitoes were killed on the island of Campobello by the sun-dew.

MR. UNDERWOOD. You have probably noticed, if you have been at Campobello at certain seasons of the year, that there are plenty of them left.

MR. FULLER. I should like to ask Mr. Underwood how it is

* Mechanical Engineer, Boston, Mass.

that some years there seem to be a great many more mosquitoes than there are other years. At my house this last summer we were very much troubled with them. There was no stagnant water and there were no pools of water anywhere about, and I don't know of any tin cans or anything of that kind lying around to hold water, and yet it seemed to me that we had ten times as many mosquitoes last summer as we ever had before. I would like to get some idea what the cause might have been.

MR. UNDERWOOD. The conditions last summer were very favorable for mosquitoes and unfavorable for us. We had periods of rain in June which extended for a long while, which made more than the average number of puddles for mosquitoes to breed in. After that we had very warm weather for quite a long while and the eggs which had been deposited in these puddles came to maturity, and we had swarms of them all over this eastern section of the country. It was merely that the weather conditions were just right last summer for the breeding of mosquitoes. Of course, in an exceptionally dry summer we won't have many mosquitoes, because the pools will dry up, but last summer conditions were just right for them. Mosquitoes will travel quite long distances under certain conditions, where a prevailing wind is blowing, not violently but rather moderately, for many hours. Mosquitoes have been known to travel under those conditions 20 or 30 miles. Vessels coming in towards the Jersey coast will meet the typical Jersey mosquito that distance out at sea.

MR. AGNEW. Have you ever heard of the castor bean being used to drive away mosquitoes?

MR. UNDERWOOD. I have read of it.

MR. AGNEW. I have lived in the South a good many years, in the south of Florida, where they are troubled with a great many mosquitoes, and it was a practice among the natives there to use the castor bean to drive away mosquitoes. Personally I never saw that it did any good, but I know it was used by the natives.

MR. UNDERWOOD. Castor oil is very effective.

MR. AGNEW. This was the castor bean just as it grows.

MR. UNDERWOOD. I don't know about the castor bean, but I know that castor oil is effective.

SOME NOTES ON COST OF WATERPROOFING THE CONCRETE LINING OF RESERVOIRS.

BY W. C. HAWLEY, CHIEF ENGINEER AND GENERAL SUPERINTENDENT PENNSYLVANIA WATER COMPANY, WILKINSBURG, PA.

[*Read January* 13, 1904.]

Concrete has been very commonly used for lining reservoirs for the storage of water. For this purpose it is laid like a pavement, generally about six or eight inches thick, on a layer of puddle. The concrete is usually of good quality and the top surface, from one-half to one inch thick, is a rich mortar, carefully troweled and ironed. This gives a clean, hard, durable surface, of good color and appearance, but it is not waterproof, and for this quality dependence is put upon the puddle. To prevent leakage, the concrete is sometimes given a coating of asphalt or other impervious material; but this is not making the concrete waterproof, but preventing the water from coming in contact with the concrete. It is a very expensive operation and renders the reservoir unsightly, especially if, as frequently happens, the heat of the sun causes the asphalt to soften and run.

Concrete is made up of a mixture of various quantities of broken stone or gravel, sand, and cement. The theory of the mixture is that the finer particles fill in the voids between those that are coarser, and by a proper mixture a practically solid mass results. The limit is the degree of fineness to which the cement is ground. Experiment has shown that by great care small amounts of concrete can be made which are practically impermeable, but it is not possible to make concrete in large amounts which shall all be waterproof; and even if it could be one, it would be too expensive.

What is needed is some way of filling the minute spaces which allow the water to pass through the concrete. If the leakage will not endanger the stability of the reservoir, and the value of

the water in the reservoir is small, the loss may be permitted, and the concrete may ultimately become tight by retaining the silt or solid matter which is filtered out of the water which passes through.

The United States Government has, in recent years, used linseed oil to render concrete waterproof. The surface of the concrete is cleaned and must be dry. Two coats of linseed oil are then applied, the second after the first has dried. The oil soaks into the concrete, and, upon oxidizing, it fills the voids and renders the concrete waterproof. This is an expensive process, however, and its lasting qualities are yet to be proved.

The oldest and probably the most satisfactory means of rendering concrete (or other masonry) waterproof is what is known as the Sylvester process, and consists of applying a wash of a solution of soap, which is allowed to soak into the surface of the concrete, and is then followed by a wash of a solution of alum. The soap enters the voids of the concrete and is followed by the alum. Where these two unite the chemical action precipitates an insoluble compound, which fills the voids in the concrete and renders it impermeable. It is this method and some variations of it to which this paper would call attention.

In a paper read before the American Society of Civil Engineers, in May, 1870, Mr. William L. Dearborn described the use of Sylvester's soap and alum process as used for waterproofing some of the walls of the gate houses of the Croton Reservoir in Central Park, New York City. This work had been done in 1863, and the results obtained are stated to have been entirely satisfactory.

It seems strange that so simple a process should have been known for so many years and should not have come into more general use. Possibly the cost of doing the work, which is stated to have been 10.06 cents per square foot, has deterred others from using it. In view of the cost of some recent work of this kind, it would be interesting to know what the materials cost in 1863, and how it was possible to spend ten cents per square foot. The process is now coming into very general use, and its cost and the cost of some modifications of it may prove of interest.

About a year ago the Apollo Water Works Company constructed a slow sand filtration plant. The water, after being fil-

tered, passed into a covered concrete clear water well or reservoir, which, after completion, was found to leak. Mr. Edward Cunningham, the assistant engineer in charge of construction, conceived the idea of making it water tight by plastering the inside surfaces with a mortar in which the soap and alum were mixed. The soap — a light-colored soft soap — was dissolved in the water in a proportion of one and a quarter pounds of soap to fifteen gallons of water. Three pounds of powdered alum were added to and mixed with each bag of cement. The mortar was mixed in the proportion of two parts of sand and one of cement, and moistened with the water in which the soap had been dissolved. Two coats of plaster were applied, with a total thickness of about one-half inch. Adding soap and alum improved the working qualities of the mortar, and the only difficulty experienced was on account of the intensely disagreeable odor while the mortar was being applied. This nauseated the masons occasionally, but did not last but a few days. It was probably caused by the quality of soap used and because the work was done in an enclosed space. The mortar was applied when the walls were dry, and the results were entirely satisfactory. The walls which leaked badly before have been to all appearances perfectly tight since.

The cost of this waterproofing in a one to two mixture was as follows:

Soap, 2 pounds (with 24 gallons of water)	@	$0.07½	$0.15
Alum 12 pounds	@	.03½	.42
Total, per barrel of Portland cement used .			$0.57

By purchasing in larger lots and a cheaper grade of soap, this cost could probably be reduced to from forty to forty-five cents per barrel of cement used.

The question might be asked, "What effect does the soap and alum have upon the setting and strength of the cement?" This depends upon the amount of soap and alum used. The amounts used as above possibly delay the time of setting slightly. The alum would increase the strength of the cement, as shown by experiment, as much as 50 per cent. The soap would reduce the

strength of the cement slightly, and, if used in considerable quantity, would cause checking and cracking of the cement. Used together, it is doubtful if the strength of the cement is altered appreciably, as one acts chemically upon the other, thus neutralizing the effects of both.

A few months ago it became necessary to make some repairs to what is known as Reservoir No. 2 of the Pennsylvania Water Company, which is located back of Braddock. In the course of the work it was found that in places the concrete had been laid directly on the rock, which was a seamy shale, and that the concrete was of a poor quality, from four to six inches in thickness. It was deemed advisable to try to make this concrete waterproof, and the process was the "Sylvester" process, as described by Dearborn. The soap solution was made of what is called Olean soap, in a proportion of three fourths of a pound of soap to one gallon of water, and the alum solution was made of one half pound of alum and four gallons of water. Both the soap and alum were perfectly dissolved, the soap solution being boiled in order to insure this result. The surface of the concrete was swept and scrubbed in places, and, after it was perfectly clean and dry, a wash of the soap solution was applied, it being put on at a boiling temperature. Twenty-four hours later this was followed with a wash of alum, and, after another twenty-four hours a second wash of soap, and twenty-four hours later a second wash of alum was applied. In applying these washes four sets of men were used, three men in each set. Two men applied the solution with whitewash brushes, while the third carried the solution to them in a pail. In making the soap solution it was necessary to have two men attend to the four kettles used to dissolve the soap, two men to carry the solution to the men using it, and one man to keep up the fires. The preparation of the alum solution did not require so many men, as it was only necessary to put the right amount of alum into a barrel of water and dissolve it, with occasional stirring. After applying the second wash of soap, it was found that the concrete on the slope was very slippery, and that the men could only work on it while being held by a rope secured to the top of the bank. The rope was placed around two men, and they started at the top of the bank applying the alum solution,

while the third man let out the rope, as was necessary to allow the others to work down the slope. The work was done in eight and a half days and cost as follows:

1 140 hours labor	@ $0.15	$171.00		
83 „ foreman	@ .30	24.90		
83 „ water-boy	@ .06	4.98	$200.88	
Add for superintendence, 15%,			30.13	
Total for labor			$231.01	
900 pounds Olean soap	@ $0.04½	$39.00		
210 „ Alum	@ .03	6.30		
6 10-inch whitewash brushes	@ 2.25	13.50		
6 stable brushes	@ 1.25	7.50	66.30	
			$297.31	

The area covered was 131 634 square feet. Hence the cost of the two coats each of soap and alum was $2.26 per thousand square feet.

When the reservoir was filled a slight leak developed, the water coming out below the outlet pipe. It is probably the leakage from a crack or cracks in the concrete lining, and it is slowly reducing in amount.

The concrete lining of a new reservoir which has just been completed near Wilmerding was waterproofed by using caustic potash and alum in the finishing coat. A stock solution was mixed, using two (2) pounds of caustic potash and five (5) pounds of powdered alum to ten (10) quarts of water. This was made up in barrel lots, from which three quarts were taken for each batch of mortar for the finishing coat. Each batch of mortar was made of two bags of cement mixed with twice the volume of sand, and covered an area about six feet wide by eight feet long, one inch deep.

The extra cost of waterproofing this concrete was as follows:

100 pounds caustic potash	@ $0.10	$10.00	
70 „ „ „	@ .09	6.30	
960 „ powdered alum @ .03¼, .03¾, and .04		34.38	
Cost of material			$50.68
1 man mixing material 60 hours	@ .15	$9.00	
Freight, express and hauling		11.50	20.50
Total			$71.18

The total area covered is 74 800 square feet, so that the cost of the work per thousand square feet was $0.95, which shows that it is much less expensive to mix the alum and soap or potash with the mortar while laying the lining than it is to put it on with brush afterwards. The result obtained is also much better, as the waterproofing material extends all through the top coat, whereas if put on by brush, it only penetrates for perhaps a sixteenth or an eighth of an inch.

The addition of the waterproofing mixture gave the finishing coat a more compact appearance than it ordinarily has. It was found, however, that if less than two of sand to one of cement was used in the mortar, the finishing coat checked in setting. It was also found necessary to use only a clean sand, as any organic impurities soon decomposed and left soft spots on the surface where they had been.

Experiments show that care must be exercised to avoid using too much potash, as it not only has this effect on any organic matter which may be present, but it will cause checking or cracking of the finishing coat, and reduces the strength of the cement. A slight excess of alum, however, is not objectionable, as it increases the strength of the cement.

It was expected that the new reservoir would have been in service before this, but delays in getting a new pipe line laid have prevented. It is therefore impossible to state what results have actually been obtained. However, the lining appears to be perfect, and we have every reason to believe that the slight extra cost of the attempt to make the concrete waterproof has been a good investment.

DISCUSSION.

MR. J. WALDO SMITH.* This description of the different methods of rendering porous concrete water tight has been most interesting, but the writer is very strongly of the opinion that if concrete is mixed in proper proportions no waterproofing of any kind is necessary. But, in order to attain this result, the mixture should be properly balanced, and it should, also, in his opinion, be mixed very wet.

* Chief Engineer Croton Aqueduct Commission, New York City.

In work coming directly under his charge, he has had occasion, in the last few years, to use large quantities of concrete in places requiring absolute water tightness, and has not found any difficulty in achieving this result without the use of waterproofing.

The best example, perhaps, is the construction of the filtration works of the East Jersey Water Company, at Little Falls, N. J. In this plant the filter tanks proper are 24 feet long, 15 feet wide, and about 10 feet deep. The side walls of these tanks are 18 inches thick at the bottom and 6 inches at the top, and there is absolutely no percolation through the wall. The concrete used in its construction was mixed exceedingly wet, and these tanks also received a coat of plaster on the inside. The basin walls, having a head of 44 feet of water against them, are about 23 feet thick at the bottom and 2 at the top, and are composed of a mixture of one part Portland cement, three parts sand, and seven parts of broken stone, all mixed very wet, which has resulted in an impervious wall.

There is also in this plant a standpipe 44 feet high and 10 feet in diameter, composed entirely of concrete, with, of course, iron strengthening rods imbedded. The walls of this tank are 18 inches thick at the bottom and 12 inches thick at the top.

With a full head of water in this tank, 44 feet, the walls were tight, and, for the most part, perfectly dry on the outside.

From experience gained in the construction of this plant and in other works, it would appear that the most essential thing necessary to make water-tight concrete is to determine carefully the ingredients to be mixed and to use plenty of water in the mixture, and also be especially careful that all the voids are filled and the exterior surfaces left smooth.

Mr. Frank L. Fuller. I have had very good results from using simply a brush coat of pure cement, about the thickness of gruel, applied with a brush. It was inexpensive, and in a great many places has answered the purpose very well indeed. By putting on several coats it is possible, I think, to make a wall water tight. On the bottom of a reservoir I think, as is suggested in the paper, it is a good idea to have the upper surface composed of mortar, of perhaps two of sand to one of Portland cement, and then possibly a brush coat on top of that, although if the bottom

is of good material, I should hardly think a brush coat was necessary.

MR. EDWARD S. LARNED. I do not know that I can add anything to Mr. Smith's remarks on the imperviousness of well-made concrete. I quite agree with him that artificial measures are not necessary to make concrete water tight if proper care is used in the mixture, and it is of the right proportions. I think the results will be uniformly as satisfactory as he has stated. One of the greatest difficulties in making the concrete lining of a reservoir water tight, I believe, is the liability to expansion and contraction during the operation of placing the concrete; and some very interesting experiments have been made in connection with the Jerome Park Reservoir to overcome this difficulty, by covering the work until completed with wet cloths and sand. Owing to the magnitude of that work, of course it is very much more difficult to carry it through to a satisfactory completion than in the case of a smaller reservoir, but I think engineers will agree that some sort of protection is very necessary.

There is quite an interesting discussion of this topic in the August proceedings of the American Society, and the Sylvester wash is described there in some detail, together with several other expedients tried. One of the cement manufacturers has suggested a small addition of lime putty as being a very valuable aid to the impervious qualities of cement mortars. There is going to be more or less investigation of this subject, and I think we are quite in the way of knowing a good deal more about it in the very near future.

MR. W. C. HAWLEY (*by letter*). It was not the intention of the writer in presenting this paper to recommend the Sylvester process as the only method by which concrete can be made water tight. He agrees fully with Mr. Smith that with a properly balanced mixture, put into place very wet, the same end can be accomplished. Where the concrete is built up in vertical molds, this can and should be done, but in lining the slopes of a reservoir embankment, say 1 on $1\frac{1}{2}$ or 1 on 2, a very wet mixture cannot be used, and it becomes more difficult to secure imperviousness. On a reservoir bottom a wet concrete can be used, but it is a question whether or not the usual 6 or 8-inch layer will be water

tight under the 15 to 25 feet or greater heads to which such linings are often subjected. The alternative is either to use a thicker layer of concrete, with its extra cost, to say nothing of either extra excavation to allow for the extra thickness, or a sacrifice in capacity of reservoir, or else to use some waterproofing material. It seems evident, therefore, that if so simple a process as the one described in the paper can be applied for a cost approximating $1.00 per thousand square feet, it is money well invested.

The brush coat of pure cement mentioned by Messrs. Smith and Fuller is a very efficient means of waterproofing, but the writer's experience with it is that it leaves a dull, rather rough appearing surface, instead of the fine, hard, smooth surface of the mortar containing proper proportions of soap or lye and alum. This would not be objectionable in a covered basin, though if more than one brush coat of cement were necessary, the soap and alum process — mixing them in concrete as it is made — would probably cost less.

One of the questions yet to be settled is, What are the best proportions of soap or lye and alum to be used? In determining this, not only must we keep in mind the effect of the mixture in making the concrete impervious, but also its effect on the strength of the concrete. The writer has recently made some experiments on the effect of the alum and lye on the tensile strength of Portland cement. Briquettes were of neat cement, and of 1 to 1, 1 to 2, and 1 to 3 mixtures of cement and sand. Nine briquettes of each kind were tested without the addition of lye or alum; 9 of each kind with the addition of alum to the amount of one per cent. of the weight of the cement, and lye (commercial caustic potash) to the amount of one sixth of one per cent. of the weight of the cement; and 9 of each kind with alum, two per cent., and lye one third of one per cent. Three briquettes of each set were broken in twenty-four hours, three in seven days, and three in twenty-eight days. The number of tests is, of course, too few to be conclusive, but the results show that the alum and lye have very little effect on the cement when used in these proportions, except to slightly delay its setting.

THE DETECTION AND PREVENTION OF WATER WASTE AT MARION, OHIO.

BY EDWARD H. COWAN, SUPERINTENDENT MARION CITY WATER COMPANY.

[*Read March* 9, 1904.]

Marion is a rapidly growing little city, with a population, in 1890, of 8 327; in 1900, 11 862; and at the present time (1904), about 15 000. It is situated on the divide between the Mississippi and the St. Lawrence rivers, only a few miles from the line separating those two great watersheds. The city water supply is obtained partly from an impounding reservoir excavated through a stratum of clay into a water-bearing gravel; and partly from a series of ten 10-inch drilled wells, from 100 to 200 feet deep, reaching into the limestone formation which underlies the country around.

During the lawn sprinkling season of 1900, it was with the greatest difficulty that enough water could be obtained to supply the city. The water in the wells was so far below the level of the pumps, as they were then located, that only a small amount could be drawn from that source. The average daily consumption for the year 1900 was 825 692 gallons, or 1 290 gallons per tap. It was considered that this was excessive, and from that time on greater attention has been given to the detection and prevention of waste. It is the purpose of this paper to describe some of the methods used and results obtained.

It was thought that the greater part of the leakage was on the customers' side of the curb cocks, and subsequent events have shown that this view was correct. The installation of meters was decided upon, and has been going on ever since. The water works plant is owned by a private company, and under the terms of its franchise a customer has his choice whether he will pay fixture or meter rates, in the latter case furnishing and maintain-

ing his own meter. It is thus impossible to place a customer on a meter basis against his will, unless he be found wasting water, in which case the franchise provides that he may be required to buy a meter and pay meter rates, or his water may be shut off.

The policy adopted was, therefore, that the Water Company should place a meter on the service pipe of each fixture-rate customer who should continue paying the same rate as before, so long as the meter showed him not to be wasting water. A monthly allowance is made for each individual customer, and if he uses more than this amount a postal card notice is sent him, to the effect that his meter indicates a large waste of water, which must be stopped.

If at the end of the next month he is still using more than his allowance, the same notice is sent again, with the words "Second Notice" stamped across the face. At the end of the third month the following is stamped on the postal card: "Last Notice. We have already sent you several notices to this effect. If the amount used next month indicates a waste of water, you will be required to buy the meter and pay by the thousand gallons." At the end of the fourth month he is required to buy the meter as above, and pay the original cost of setting it.

The monthly allowance for any customer is obtained by dividing his monthly fixture rate by the regular meter rate per thousand gallons. If a customer should consume exactly his allowance each month, he would be obtaining water practically at meter rates, yet with the Water Company furnishing the meter, instead of the customer. The margin between what he does use and what he is allowed to use may be said to reimburse the Water Company for setting and maintaining the meter.

Before adopting a plan of this kind a water works company should carefully determine if its meter and fixture rates bear proper relations to one another. The rates should be such that the company would not suffer if fixture rates were abolished, and all customers paid by meter, taking into account the lesser amount of water required in such case. In this city we were influenced by the probability that we should be put to great expense increasing our water supply unless waste could be largely reduced.

We have had very little friction with our customers in carrying out this plan, as its fairness can be easily shown to almost any one. We have found a few customers who seemed to be legitimately using more than their allowance, while many others were not using one tenth of theirs, which goes to show how inequitable a fixture or flat rate system is.

Meters have been placed in school and city buildings and churches, all of which are supplied with water free, and especially in the school buildings have the meters paid for themselves many times over in restricting waste.

Whenever possible, meters are placed in cellars. In some cellars it has been found necessary to protect the meter from freezing. This has been done by building a rough wooden box around it, enclosing all the pipe back of the meter and inside the cellar wall, and as much of the pipe ahead of the meter as practicable. The top of the box is left open and it is filled with sawdust, which can be brushed away when the meter is read.

Even with such protection it is found that occasionally a meter will be frozen, on account of the water in the pipe outside of the box freezing, and the ice gradually extending back to the meter. The cost of labor and material for taking out, repairing, and resetting a meter averages about $1.00.

In a building which has no cellar the meter is, if possible, set under the floor at the point where the service pipe enters the premises. A wooden box filled with sawdust as above described is usually required, and a trap door is made in the floor to provide access. It is seldom that a meter set in this manner freezes.

When yard hydrants or other outside fixtures are in use, or when for any other reason it is impossible to set the meter in either of the places mentioned above, it is set in a meter box out of doors. The box now used for this purpose is shown in Fig. 1, and was invented and patented recently by Mr. B. C. Palmer, street foreman for the Water Company, and the writer. It is made of iron, and is cast in two halves for convenience in molding. The halves are fastened together at diagonally opposite corners by bolts. The cover is held on by a bar attached to the pentagonal-headed bolt which passes through the cover. The bar engages two wedges inclined in opposite directions, so that

a quarter turn of the bolt will fasten or unfasten the cover. A second cover of wood rests on a flange cast on the inside of the box about twelve inches below the top. The air space between the two covers has never yet failed to keep the meter from freezing.

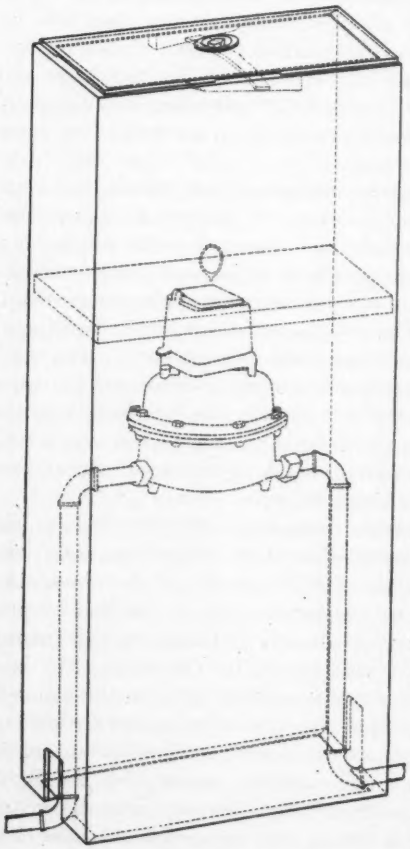


Fig. 1. — Cast-iron Meter Box.

The meter inspector on his monthly rounds listens at every tap where it is possible to do so, and reports any case where there seems to be a leak back of the meter. To do this requires some time, but it is time well spent, as one or more leaks are found every month.

Since January, 1902, all taps have been laid with lead pipe by the Water Company's own men, including worn-out ones. Previous to that time galvanized iron (or steel) was used, and many of the older ones are giving out.

Nearly all the soil in this vicinity is impervious to water, and leaks are not long in showing at the surface, unless, as occasionally happens, they be close to some drain which furnishes an outlet to the water. In considering the large amount of water pumped in 1900, it was thought that this might not be the case and that there might be

many leaks not appearing at the surface. Consequently it was decided to make a complete survey of the entire system to determine if this were true.

The apparatus used consisted of a horse and wagon, a 1½-inch Gem meter, 9 fifty-foot lengths of 2½-inch hose, gate keys, curb cock wrenches, and lanterns. The writer took personal charge of the work and was assisted by two men, one of whom was an old employee, familiar with the system. The work was done between the hours of 10 P.M. and 5 A.M., but in larger cities it would not be best to start so early.

After two or three nights it was found unnecessary to follow out in detail the original plan, but that certain modifications might be made which would greatly facilitate the work without making it any the less thorough. The original plan of operations will first be described, and afterward the ways in which it was modified.

Two gates were closed, thus cutting out the section to be tested. This section will be referred to as a "block," although in some of the older parts of the town, gates are as many as three or four blocks apart. A line of hose was laid from the nearest "live" fire hydrant to a "dead" one, and the meter placed in the line next to the "dead" hydrant. Both hydrants were then opened, and if the meter showed water to be passing into the "dead" block, its rate of flow was noted, and one of the men started to close the curb cocks in that section.

Careful watch was kept at the meter, and if after closing any curb cock the rate of flow diminished suddenly, or ceased entirely, it was concluded that either there was a leak on that service, or the customer was using water, and an investigation was made to determine which was the case. Whenever the flow ceased entirely, the investigation of that section was at an end. After closing all curb cocks, if water was still running through the meter, one or more leaks were shown to be in the "dead" block, and they were located in every case by listening at the curb cocks.

The work went on in this manner, block after block, for several nights, resulting in the finding of only two or three leaks. The writer then concluded to try four or five blocks at once. In this case quite a number of gates had to be closed, and most of

them were attended to in the daytime, leaving only as many to be closed in the night as were required for efficient fire service. At the first trial the meter stood still, so from that time on still larger sections of the town, containing from two to three miles of mains, were cut out and tested at once.

When a leak was found its rate of flow was noted, as before, and then the size of the "dead" section was reduced one block at a time by opening and closing the proper gates, working towards the meter. In this manner the block or blocks on which there were leaks were located.

After the first few nights the shutting off of curb cocks was discontinued, as very few leaks were being found, and those could be easily located, in the stillness of the night, by placing the ear against one end of the street key, holding the other end on the curb cock. In down-town sections of larger cities, however, where there is more or less noise from teams all night, it might be best to shut off the curb cocks.

When testing two or three miles of mains at once, a simple system of lantern signals was used between the man at the meter and the men who were opening and closing gates. Sometimes these latter were nearly a mile away from the meter, and without signals much time would have been consumed going back to it after cutting in each new block. The 1½-inch Gem meter was used, not because it is the best size or kind of meter for the purpose, but because it happened to be available. It has hose couplings, and is in regular use for measuring water taken from fire hydrants for miscellaneous purposes. Were the writer to do this work over again he would use a smaller meter of the piston or rotary type.

The method of finding leaks in street mains and services above described proved perfectly successful, as well as economical. It is thought that no leak escaped detection. The failure of a gate to close tightly was considered but the effect of such a case would have been only a somewhat reduced rate of flow through the hose and meter. Tests for unauthorized connections might be made in a similar manner in the daytime, first closing all known curb cocks. By taking one block at a time, patrons need be deprived of water for only a short period.

The effect of the above and other less important methods of discovering and restricting waste is shown by the following statement: The average number of taps in use in 1900 was 640, of which 32 per cent. were metered; in 1903, an average of 891 taps were in use, 72 per cent. of which were metered.

Average amount of water pumped daily per tap in 1900,	1 290	gals.
„ „ „ „ „ „ „ „ „ 1903,	648	„
Difference	642	„
Decrease due to loss of five large customers	272	„
„ „ „ restriction of waste	370	„
Estimated portion due to installation of meters, 0.8 of 370,	296	„
Total annual saving due to installation of meters, 296 x 365 x 891	96 263 640	„

This may be regarded as a fairly close estimate of the amount of water which would have been pumped in 1903 in addition to what was actually pumped, had there been no meters placed on other than the usual proportion of new services, whose owners prefer to buy meters and pay meter rates. This saving has been brought about by the installation of 240 company meters, each meter thus being credited with 401 098 gallons.

In order to make sure that this amount is not overestimated, we will divide it by two, which gives, say, 200 000 gallons annual saving per meter. The cost of fuel and lubricating oil required for pumping 1 000 gallons is $0.0094, or $1.88 for 200 000 gallons. Deduct 17 cents, which is the annual cost of reading a meter, and 13 cents, the cost of maintenance, leaves $1.58, which, at 6 per cent., represents the annual interest on $26.33. This is a little less than double the cost of setting the average meter.

As stated above, enough meters have been set to increase the number of metered services from 32 to 72 per cent. of the total. It should be understood that meters have now been placed on all taps where there was especial likelihood that water was being wasted, such as saloons, livery stables, and stores, and that the remaining 28 per cent. represent mainly small customers having but one faucet or one yard hydrant. It will be seen that the meters which have been set by the Water Company have paid for themselves nearly twice over, in saving of fuel and lubricat-

ing oil alone. In addition, the expenditure of large sums for increasing the available water supply has been postponed at least five years, and probably more, as a direct result, not to mention lesser savings, such as wear and tear of machinery and boilers.

FIRE PROTECTION FOR FACTORIES: HOW ITS VALUE SHALL BE DETERMINED AND WHO SHALL PAY FOR IT.

BY J. H. PURDY, PITTSBURGH, PA.

[*Read February* 10, 1904.]

When the Secretary asked me to say something upon this subject, I thought I was going to be able to hunt up some data that would have a fixed value for the Association. Unfortunately, I was called away from home and didn't get back until Monday of this week, and when I began to look up authorities from which I could make an article, I was astounded at the absolute lack of authorities upon this subject. However, I prepared a little paper here that raises some questions and gives some ideas of the questions.

"Fire protection for factories: how its value should be determined, and who should pay for it." The rapid stride and growth of our towns and cities have brought us many problems. The development of the small mill or shop to the great factory building, or group of buildings, filled with costly machinery and raw and finished materials, has forced the question of how best to protect such buildings and their contents from fire upon the careful attention of not only the owners of such properties, but also of insurance companies, municipalities, and water companies, and by first glancing at the interests of each in the protection of such properties, it will no doubt assist us in forming some conclusions as to kinds of protection or part the water departments or water companies should take in furnishing special facilities for fighting fires on such premises. In most cases the city authorities are liberal in placing fire hydrants in near and handy locations to large factories, if the water works are owned by the city; if by a company, the city usually orders hydrants placed by the company handy to such buildings; if it is a town of some size, chemical

engines, steamers or hose carts, with all modern appliances, are provided by the city or town authorities and kept conveniently near for ready use. In addition to this, the proprietor usually has grenades, or small fire extinguishers, placed at convenient places throughout the premises.

All of the devices and means mentioned are generally provided and maintained by the municipal authorities and the mill proprietors, and are only mentioned to show the joint interest of the authorities and the owners, and to distinguish them from the special means of protection to which our subject refers. Under this heading of special protection, we may divide it into three classes:

First. Fire hydrants on the premises, usually having threads or nozzles interchangeable with the hose of the city fire department.

Second. Standpipes in the building with hose attachments at convenient places on each floor, having hose attached at all times ready for instant use; in many cases with valves which open automatically as the hose is unrolled and brought into action. Water departments and water companies usually insist that the pipe lines leading from their mains to such inside fire hydrants or standpipe lines shall not be tapped or used for any other supply. Insurance companies have objected all along to the placing of meters upon any such supply or any restrictions that would in any way interfere, as they thought, with the free use of such lines. There will be made to-morrow, in Burlington, Vt., some tests of meters upon such fire supplies by the New England Fire Association. To that test invitations were issued to the General Committees of the American Water Works Association, and I was appointed upon a committee at the American Association last year on insurance, involving some of these questions. But I only digress to show this question of special fire protection is a new one and coming into prominence in every manufacturing district, forced upon us by the insurance companies.

Third. The sprinkler system has come into extensive use in the last few years as one of the most effective means of preventing disastrous fires in factories and stables by putting out the small blaze and stopping the fire at the start. It consists of a network

of pipes, usually hung to the ceiling of the different rooms or departments. Such pipes are generally run along over the shafting and over points in the rooms where there is thought to be the greatest danger of fire starting. Attached to these pipes at every point where there is danger of fire are sprinkler heads screwed into the pipe. Parts of the sprinkler heads are made of soft metal strong enough to withstand the ordinary pressure on the water pipes but soft enough to melt from the heat of a fire occurring near them, and they are so constructed that when the part melts the water under pressure is sprinkled upon everything in its immediate vicinity. As the sprinkler pipes are kept constantly full of water under pressure, the opening of these heads letting out the water directly over the fire at its start usually prevents its spreading. The usual method of connecting is to have pressure on the sprinkler system maintained from an elevated tank, but in addition there is always a direct connection from the street mains. The tank is used because there is no fluctuation of pressure, the soft sprinkler head being weak and liable to break and leak under a variable pressure. It is thus seen that all of these plans for putting out fires, either small or large, rely upon the water department or water company for a certain and ample supply of water, always ready and in sufficient volume and pressure to meet the maximum demand of those who rely upon any or all of the means described.

To meet this requirement the water departments or companies have been compelled to plan and build on a much larger scale than they would if the only demands upon them were to furnish water for domestic uses or the supply of boilers, etc. Supply lines and street mains, pumps, boilers, and reservoirs must all be planned on such a scale as will meet the requirements of fire hydrants and sprinklers in addition to the domestic and manufacturing demands.

How shall the value of this special service be determined? Plainly, metering the water going through these special lines would not compensate the water department or water company for their extra investment in the larger reservoirs, pipes, pumps, and water supply needed, as the hydrants, standpipes, or sprinklers may be in position for years without being called into use, so that

the only just and fair way is to fix a charge based on the size and capacity of the fixtures erected and the amount of water which you have placed at the disposal of the party owning the premises and erecting the hydrants, standpipes, or sprinklers. In some places a charge is made per year for each sprinkler head. At others an attempt has been made to arrive at a rate based on the area of floor or space protected. Another method has been to base the charge on the size of the pipe connection to the water company's mains, but all of these are only means of fixing the amount or volume of service rendered, and the value of it must be determined by agreement between the parties.

Insurance companies will name a certain premium where sprinklers are used and a higher rate where they are not. The difference between these amounts is the money value per year the insurance companies place on these special facilities. If we can now get the value of the plant or goods protected or the amount of insurance carried, we can readily calculate the annual cash saving, from which must be deducted interest on the cost of installing the sprinkler system, and I think an equal division of the remainder between the owner and the water company would be fair value for the service, and would certainly be fair to the owner, as he gets one half of the insurance saving and has the added security against interruption of business and damages not covered by insurance. Charges for standpipe and hydrants are usually the same as the city or town pays per year for its fire hydrants. Where the plant is owned by the city, I cannot find that there is any custom.

The argument is frequently made that these appliances are so rarely used, and so little water during the year is required of them, that no charge should be made for them beyond the value per thousand gallons of water used. This is as surely wrong as to say if you chartered a railroad train for a year and held it under steam for your use the entire time but only found it necessary to make one journey, that you should only pay ticket fare for the one trip. Now who should pay for the special service? The community is surely interested in protecting the property of the factory or business which has done so much for the prosperity of the town, but has it not discharged its obligation when it gives

to it the same measure of protection which it gives the smaller business store or shop, or the residence, barn, or office of any other citizen? Insurance companies are, of course, interested parties, but as their premiums are reduced in proportion as these special means of protection are provided, or are increased if they are lacking, and as the reduction in premium remains in the owner's pocket, in whose name and for whose benefit the policy is written, it seems to me that payment for the use of the water department's or water company's facilities to the extent and in the manner described should be made in every case by the property protected just as much as they should pay for the small tap or supply for ordinary uses. In these special protection cases the department or company places, subject to the emergency needs of the owner of the factory, pipe connections so large as to form a large percentage of the pump, reservoir, or supply main capacity. Bear in mind also that pump, reservoir, and supply main have been built and must be maintained and enlarged on a much more liberal scale than would be required if it were not for this special service, and there is no question, in my mind, that the property owner should pay for the special service.

REPORT OF COMMITTEE ON PRIVATE FIRE PROTECTION.

[*Presented February* 10, 1904.]

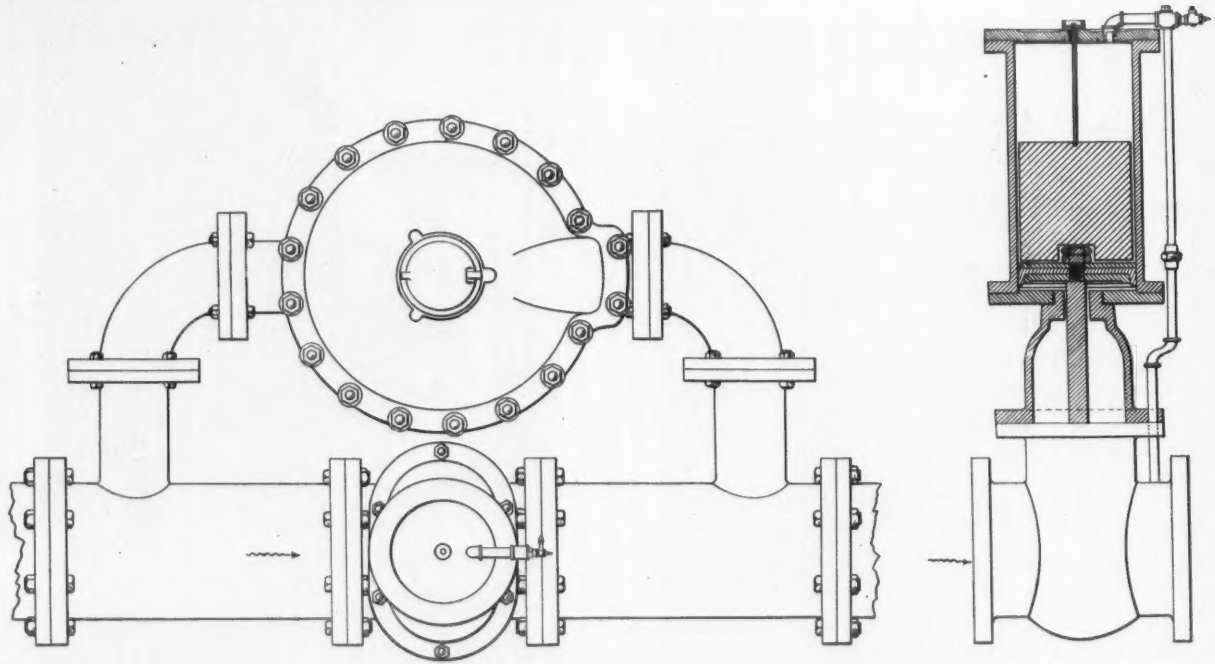
Since our report, made at the Montreal meeting, Mr. Tilden, of the Hersey Manufacturing Company, has submitted to your Fire Pipe Committee a device designed to overcome the most unsatisfactory feature of the control of large services, at that time pointed out, viz., The inability to accurately measure for any considerable length of time the smaller flows, leaks and waste.

Mr. Tilden's device for accurately measuring small streams and delivering, either with or without registration, larger streams without objectionable frictional loss, consists of a meter, — in the device submitted a 3-inch meter, — set in a by-pass around a double faced gate valve with parallel seats, the face toward the pressure being bored to admit of the passage of water through the same, and thence up around the stem into a cylindrical chamber directly above the valve, through the center of which the valve stem extends (see Fig. 1).

In the cylindrical chamber, attached to the valve stem, is a cup-leather plunger, placed cup down, or against the pressure, and weighted to such extent as with the weight of the valve and stem to constitute a force tending to keep the valve closed, equal to the pressure per square inch which it is designed to absorb in the apparatus.

The stem above the weighted valve extends as a light rod, or pin, through a stuffing-box at the top of cylinder, and by its position, either just protruding through the stuffing-box or extending above the stuffing-box, a distance equal to the motion of the valve or less, indicates its position.

The cup-leather packed valve-operating plunger is, as regards the pressure from the lower or inlet side, absolutely tight. The valve itself is, as used, a single faced gate, closed by the pressure.



PLAN. SECTIONAL ELEVATION.

FIG. 1. — Tilden Device for accurately measuring small flows, and permitting the passage of larger flows without registration and with but slight frictional loss.

The pressure at the inlet, conveyed through the hole in the valve, and up around the stem to the under side of the valve-opening plunger, is balanced by the pressure on the outlet side of the valve, the same being conveyed to the top of the plunger through a brass tube (shown in Fig. 2, Plate I, and Fig. 1, Plate II).

Under static conditions, inlet and outlet pressures being equal, the valve is held down by the weight of its parts, and on experiment was found to be tight, and to remain so until, by reason of the inability of the metered by-pass to deliver water as fast as required, the pressure on the outlet side dropped to about 5 pounds below that on the inlet side of the device. At this point the discharge was about 175 gallons per minute.

As the demand for water, for fire or other purposes, increases, and the outlet pressure diminishes, the difference of pressure on the two sides of the valve-operating plunger causes the same to rise, maintaining until the valve is wide open, a difference in pressure between the inlet and outlet not in excess of that for which the device is designed, — in case of the device tested, about 8 pounds.

Tests were made under varying rates of flow, from 1.2 gallons per minute, to about 2 600 gallons per minute, all of which tended to substantiate the claim of the inventor, that the device could be relied upon to accurately measure streams up to its designed capacity, and to deliver, without excessive frictional loss in the device, larger streams, up to the capacity of the supply.

For the purpose of securing information in regard to the opening of the automatic gate, a wax seal is placed over the pin extension of the valve stem, which, on the opening of the valve, is broken by the rising pin.

A stop in the brass tube through which the outlet pressure is conveyed to the upper side of the operating plunger, and a petcock on the top of the cylinder, by the opening of which the upper or outlet side of the plunger may be exposed to atmospheric pressure, together enable the manual operation of the valve for purposes of inspection and test, or for the purpose of removing the resistance normally imposed by the device (see Fig. 1, Plate II).

There being practically no flow through this brass tube, its function being simply to transmit pressure, and it being of non-

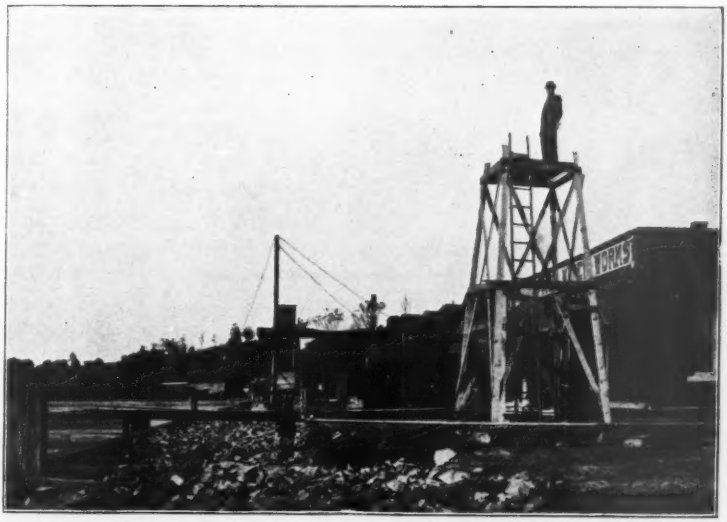


FIG. 1.—General view of testing apparatus for large streams, showing discharge into Lake Champlain on the left and pumping station buildings on the right.

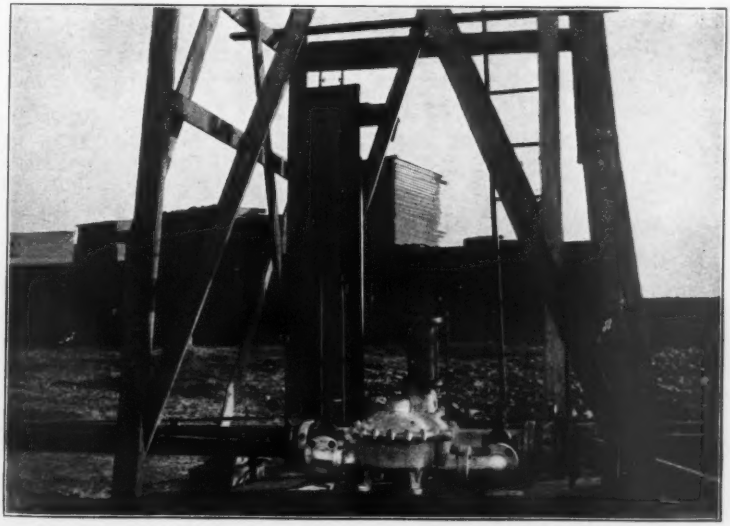


FIG. 2.—Tilden Device in testing apparatus at Burlington, showing metered by-pass around automatically opening gate between piezometer rings in foreground. In the background, on the left, U mercury gage for determining frictional loss in the device; on the right mercury nozzle gage for determining nozzle pressure.

corrosive metal, there is no chance for accumulation or clogging of the tube, and no advantage to be derived from an increase of its diameter. While lengthening the tube to the vicinity of a probable point of discharge would result in a wider opening for a given discharge, the gain would be slight, and more than offset by loss of compactness.

The sticking of this valve by an excessive back pressure is a very remote, not to say impossible, contingency. First, because of the equalizing effect of the metered by-pass. Second, because the capacity of the brass tube, conveying water to the outlet side of the operating cylinder, is not sufficiently in excess of the possible leakage past the reversed cup-valve to admit of the accumulation of excessive pressure on the outlet side, even were the metered by-pass absolutely tight shut. Third, because the wedge, separating the valve discs as they reach their seats, is too flat to admit of sticking. Fourth, because of the presence, in the service, of a swing check to prevent the flow of water to the main.

The sticking of the valve from lack of operation is equally improbable, for where such a device is in use, it should be inspected and operated monthly by the Water Department.

The underwriters' inspector, knowing such a device to be installed upon a risk, and failing, on his inspection, to see it operated would be guilty of gross negligence, and that, in an underwriters' inspector, would be simply inconceivable, and furthermore, the private fire services, on which such a device would not be opened several times a year for flushing sewers, watering grounds, or other cause, are extremely rare.

A back pressure of about one hundred and ten pounds, measured at the outlet piezometer ring, was repeatedly applied to the device examined for the purpose of developing a stick, which it utterly failed to do.

The best feature of this device is its adaptability to a wide range of conditions and requirements. By varying the length of the operating cylinder, and the weight of lead used therein, the amount of frictional loss required to open the valve may be made to conform to that to be spared under the particular conditions encountered.

By varying the size of the metered by-pass, the sensitiveness and range of the device, for the measurement of small flows, may be regulated to meet different requirements in that respect, from the opening of the automatic gate on a 5-pound frictional loss, caused by a discharge of about 70 gallons per minute through a 2-inch meter, or 175 gallons through a 3-inch meter, to the opening on the same frictional loss by a discharge of about 400 gallons per minute through a 6-inch meter.

A meter, full size of the service, in the main line with the automatic valve, around both of which a by-pass with a meter capable of detecting small flows, leaks and waste, is taken, will enable the registration, with approximate accuracy, of all water used, both large and small streams.

Your Committee, having carefully examined and tested the device submitted by Mr. Tilden, are satisfied that it will afford, in many cases, a satisfactory means of determining the amount of water passing through services supposed to be used for fire purposes only.

The performance of the valve under test was most satisfactory, the frictional loss being much less than might reasonably have been permitted. The device is of the simplest character, the only part subject to clogging being the meter, the clogging of which serves only to cause the automatic gate to open under a less discharge than it should. Experience seems to have demonstrated that the principle of the device, which is by no means new or untried, is excellent, and that the failure of a properly installed apparatus to perform its designed work is next to impossible.

Reaffirming the statements made in their report at the Montreal meeting, your Committee would respectfully submit their further findings, in regard to the control of large services, as follows:

In cases where a failure to register the smaller streams is deemed of little importance, a meter as sensitive as the Crown, Hersey Disc, or Empire, as tested at Knoxville, or, in case it be deemed advisable, such a meter in a by-pass around a gate, to be kept closed except in case of fire, will accomplish the desired result. Unless the failure to register the smaller streams be deemed of little importance, no large meter will, for long, be sufficiently

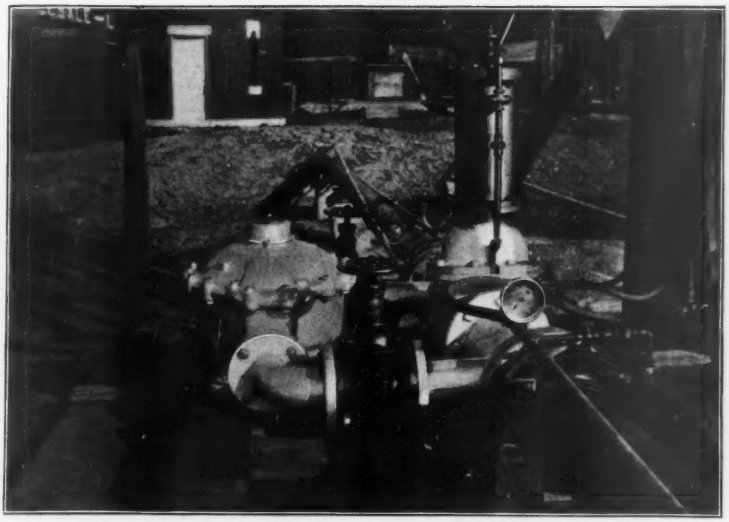


FIG. 1.—Tilden Device in testing apparatus at Burlington, as seen from outlet, showing brass tube for transmitting outlet pressure to cylinder with stop and pet-cock to enable manual operation. Metered by-pass on the left, automatically opening gate on the right. Six-inch supply line and tank for weighing discharge of small streams in the background.

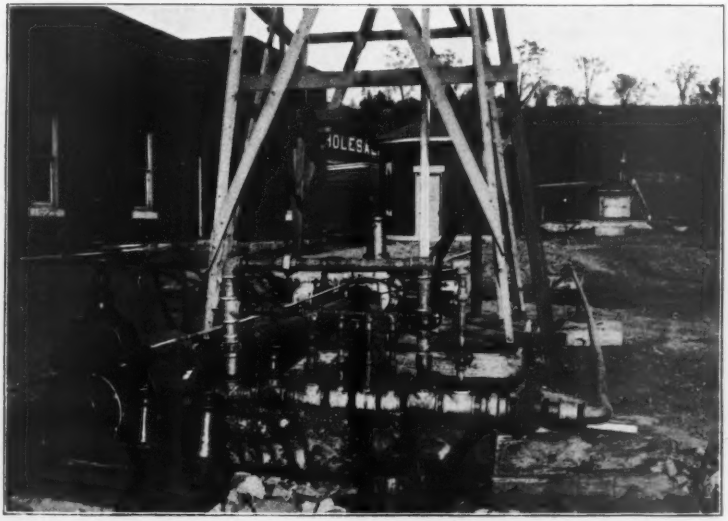


FIG. 2.—Tilden Device in testing apparatus at Burlington, showing in the foreground gridiron through which two-inch and smaller streams were drawn into tank on scales, seen in background; also six-inch gate through which streams were thrown through calibrated nozzles into the lake.

sensitive to meet reasonable requirements as regards the detection of small waste.

In cases where a failure to register the larger streams is deemed of little importance, a device, like that submitted to the Committee by Mr. Tilden, the metered by-pass being made larger or smaller as the circumstances of each individual case may require, will accomplish the desired result.

Wherever a device permitting the passage of the larger streams without registration is permitted, it should be clearly understood and agreed that in case of opening the automatic gate for any other than fire purposes, the amount estimated to have passed unregistered should be paid for, and that should its frequency of opening demonstrate the use of the service to be in excess of the capacity of the device to accurately measure, a device or meter capable of correct registration should be at once installed at the expense of the user.

In cases where the measurement, with approximate accuracy, of the entire supply is desired, a device like that of Mr. Tilden, with a meter of the full size of the service in the main line with the automatic gate, around both of which a by-pass with a meter capable of detecting the smaller streams, leaks and waste, is taken will accomplish the desired result.

While not wishing to be understood as taking the ground that no better means than those above suggested for obtaining the desired results can be devised, we are satisfied that they are the best at hand, and are amply sufficient.

Respectfully submitted,

F. H. CRANDALL,
R. J. THOMAS,
ELBERT WHEELER,
Committee on Private Fire Protection.

DISCUSSION.

MR. FRANK L. FULLER. I should like to ask Mr. Crandall how his determinations of the loss of pressure agreed with either the Ellis or the Weston tables.

MR. CRANDALL. I have not done the work in comparison which I expect to do. It was rather late in the season, and the deter-

mination of the loss in the pipe was a sort of after-thought and not immediately connected with the work in hand, so that before saying anything about it I should like to repeat the experiments and get intermediate data.

MR. FULLER. It seems as though it was a very good opportunity to get accurate results.

MR. CRANDALL. We did get some results, but I should prefer to look the matter over more carefully, duplicate and add information before saying anything with regard to the differences between the results of these experiments and the tabulated statements that we have.

MR. AUGUST FELS. I should like to state that the Lowell Water Board has bought a device like that which Mr. Crandall has explained, and what he has shown in the pictures you can see in actual operation at Lowell. If it is in order I would move that the committee be continued.

MR. THEODORE H. MCKENZIE. Do I understand that Mr. Crandall recommends that a proper rate for fire protection is one-half of the difference in the premiums paid to the fire insurance companies, — that is, the difference between what was paid without protection and what is paid with the protection?

MR. CRANDALL. That was Mr. Purdy's suggestion in his paper which I read.

MR. MCKENZIE. I supposed the committee was to make some recommendation so that water works superintendents could have some basis for a charge for fire protection. It is one of the most difficult problems that we have to encounter, the matter of establishing rates for sprinklers and hydrants and standpipes.

MR. GORHAM DANA. Mr. President, I represent the Underwriters Bureau of New England. Unfortunately I am the only insurance representative here to-day. I wish I was not, for I think there is a great deal to be said on our side. I had the pleasure of attending the tests at Burlington which Mr. Crandall has been describing, and I feel very confident in saying that the Tilden automatic valve will not be acceptable to the insurance interests. Any valve of that kind requiring a packed stem and complicated moving parts and a small pipe to convey the pressure, is a complication which we have been trying for years to avoid in

fire protection work. At present we have a dry valve which we have to contend with occasionally. They have been made as simple as possible, but they are still so complicated that we do not always grant the same rate of insurance where they are used as we do on a straight wet pipe system. Now the Tilden valve is more much complicated than any dry valve; or, I should not say more complicated, but there is more chance of obstruction in the Tilden valve than in any dry valve I ever saw, and I think the principle is wrong. I do not think we want to rely for fire protection on any valve which has a moving packed piston which is liable to get stuck and clogged by sediment, and also a small pipe transmitting pressure which is liable to get clogged and in which there is a valve which is liable to be left closed.

While in the tests at Burlington the valve worked satisfactorily, that was no test of the effect of wear and age. The only way to test such a valve is to have one in use for years under unfavorable conditions and then see what the result is; and I feel sure that in some plants that I know of such a valve would get very badly clogged with sediment. We have had cases where ¾-inch sprinkler pipes have become entirely clogged so we couldn't get a drop of water through them. Those were pipes where there was hardly any flow and much less chance for sediment than in pipes where there is a flow.

In regard to inspecting these valves, it has been said that they should be tested once a month, but I don't know of any place where the insurance companies can afford to make such frequent inspections. The average is perhaps once in six months, and the chances are that such a device would be put in places outside of New England where inspections are not so frequent as that. The thing might go a year easily without insurance inspection, and I think in such a case as that there would be a very good chance of having trouble. So far as the insurance companies are concerned I wish to say that we do not wish to accept this device without a long-continued series of tests.

Mr. Robert J. Thomas. I was present at this test in Burlington and saw the operation of the Tilden valve there for the first time, and it impressed me very favorably. Since then two of them have been purchased or ordered for trial in Lowell, and one

is now in use in our shop on a fire service. I have watched it very closely, and I cannot conceive that there is the remotest possibility of the valve sticking. I think the insurance companies in objecting to this device are either not sincere, or else they are not fully informed as to the operation of the same. Take for example the remark of the gentleman who has just spoken as to the clogging of the small pipe which conveys the pressure to the top of the valve; the effect of the clogging of that pipe would be that the valve would open and remain open; consequently it would not affect the insurance people a particle, for it would give them the full 6-inch pipe.

Now, I take it for granted that most water works men are willing that the water used for the extinguishment of fires should be furnished gratis, but they believe that the corporation or manufacturer who uses water through a fire service for any other purpose than for the extinguishment of fires should pay for it, like the humblest water-taker in the city, and that he should not have any extra privileges above the average citizen. Now, how can this be done without putting on a meter? The water works superintendent must put a meter on to arrive at the amount of water used or wasted. He should at the same time put on a device that in case of fire will give the fullest possible amount of water for the extinguishment of the fire, and where sprinklers are open will supply them all the water that the system can furnish and with the least loss of head or pressure. That is the idea of the water works man. If you put a positive meter on you will get a registration which is fairly close, but where you are drawing a large quantity of water you are going to reduce the pressure so you possibly will not have in the top of a high building pressure enough to operate your sprinklers effectively. With the Tilden device, or any device similar to this, all you have to interfere with the delivery of the water is simply the friction in the pipe. What better service can you have? If you use a current meter which will not obstruct the flow of the water as much as a positive meter, then you will not have registration of the fine streams. Then again comes the question whether or not it is important to the water works to have the small flows measured, — whether there is sufficient waste of water through leaky joints

in pipes and in other small ways which a current meter would not record.

I recently received a letter from the people whom the gentleman who has just spoken represents, proposing a system of inspection by the insurance inspectors, whereby they would report to the water works office any infraction of their rule which prohibits connection with sprinkler pipes for any other purpose than for fire protection. But we have in Lowell, — and I presume it is so in almost every manufacturing city in New England, — a number of fire services which are laid in the ground for a long distance, and some of these pipes have been laid for over thirty years. In the mill yards there are race-ways and underground water-ways of various kinds that these fire pipes cross. Now how is the insurance inspector going to tell us whether there is a leak in a pipe under a brook or river or race-way? There may have been leaks in pipes laid in this manner for years and we may have been losing water all the time, and if we were brought up before a committee of the city government and asked how we know about the consumption of water in this or that large concern, whether we were getting paid for the water used or whether we knew how much water was used, we would have to admit that we didn't know anything about it. But if we put a meter on the fire service we do know what is going on, and if we give them a meter which will furnish an efficient fire service, a bountiful supply of water, with sufficient pressure for their sprinklers and their fire pipes, making them pay for what they use for other purposes, I think we are using them right, and we certainly then can stand up before the public, the other water-takers, and say that we are using the large consumers just the same as we are using the small ones. That is what we are trying to get at, and, as I said in the beginning, I think the more the insurance companies study this device of Mr. Tilden the sooner they will come to the conclusion that a device like that is a good deal better for them than a positive meter; and if they are not willing to accept it, I apprehend that the water works people will enforce the use of positive meters on the fire services. The result will be that where one fire service will give them sufficient water without a meter, when a meter is placed, it will be necessary for

them to have two fire services instead of one and consequently two meters.

I think I am voicing the sentiment of the committee when I say that, so far as they have examined this device of Mr. Tilden's, and so far as they can understand the mechanical operation of it, they totally disagree with the insurance people in considering it possible, not to say probable, that the valve may stick. Why, the valve manufacturers have been making a valve similar to this for seven or eight years and possibly longer, which they call an automatic hydraulic valve. You can see a description of it in their catalogues. It is possible that several towns and villages where there are large manufacturing establishments are at present supplied through automatic valves of this same kind, probably not so good, because in the automatic valve known as the hydraulic valve there is a stuffing-box and the stem is packed. In this device of Mr. Tilden's there is no packing around the stem. The stuffing-box is taken out and the water passes up by the stem, making it less liable to stick than the ordinary hydraulic valve, which has been in use for years. Mr. Crandall has told you about the device which has been in operation in Burlington for seven or eight years, and he has never had any trouble with it. It has a cup-valve on it, similar to the cup-valve on the Tilden device, and he has never had occasion to replace that valve; it has never given them any trouble. I say again that in my judgment the insurance people are not reasonable in their opposition to this device of Mr. Tilden's.

MR. DANA. Mr. President, in reply to the gentleman who has just spoken, I would like to say, first, that if the small pipe which conveys the pressure to the upper side of the piston is clogged, it will prevent that valve from opening, provided the valve is closed when the clogging takes place, because in order to open the valve the pressure must be released above it, and if that pipe is clogged or allows the pressure to go in and out from above that it will necessarily keep it closed.

In regard to the necessity for such devices, that is a question which I did not start to argue, and I think it has been argued very thoroughly in this Association before from what I have been told, although I have never heard it argued myself. I think, however,

there is one point which should be borne in mind, and that is that there are different kinds of plants, some that need meters, perhaps, and some that do not. A large majority of the factories that are equipped with sprinklers have no outside piping at all. They are in cities, they take directly from the street main which is not more than 15 or 20 feet from their building, and there is absolutely no chance to tap the pipe between the street main and the building. Inside the building there is a chance, but that is looked after carefully by the insurance inspectors. And most modern plants have an alarm valve that absolutely prevents the flowage of water through the sprinkler pipes without giving an alarm, and it isn't likely that people are going to have the alarm ringing all the time in order to steal a little water. In large plants, where there is a great deal of yard piping, a meter can be placed in the yard, where the pipe enters the yard, with a by-pass which can be opened from a distance in case of fire, and that would be a comparatively safe arrangement. But the idea of making everybody pay for the faults of a few is not in my estimation correct.

MR. E. W. KENT. I have had some little experience with manufacturers who have been negligent in the care of their plants and have allowed a large waste to extend over a period of twenty-four hours. During the past month I lost 691 000 gallons of water in one plant in twenty-four hours. A line of sprinklers had frozen, some eight heads had burst, and one line of 2-inch pipe under 120 pounds pressure had blown off, so that the discharge through a 2-inch orifice continued for twenty-four hours unchecked.

PRES. E. C. BROOKS. I may say that I was rather glad to hear the gentleman who represents the insurance people say that they had found sprinkler pipes clogged. It has been a wonder to me that the insurance people put in, or allowed to be put in, plain black pipe for fire protection. We all know that plain black pipe fills up very rapidly, and it seems to me that the slight difference in cost between that and galvanized ought to be no bar to the introduction of galvanized pipe for purposes of this kind, where they are really desirous of keeping the pipe free from corrosion. And as to the Tilden device, I don't believe that there would be any difficulty about making every part of it of composition, so

that as far as corrosion is concerned it should be perfectly free from that troublesome feature. It seems as though the objection on that ground was something which is merely a matter of detail which can easily be gotten over. I should be very much pleased to hear from some of the other gentlemen as to their experiences.

MR. DANA. When I spoke of sprinkler pipes clogging I did not refer to corrosion but to sediment in the pipes. Our experience has been that in sprinkler pipes, where there is no flow, there is very little corrosion on the inside. The trouble we have is from sediment which comes from the water. I have seen pipes which have been installed fifteen or twenty years taken down, and they were almost as clean inside as when they were put up, so far as corrosion was concerned. It is the sediment which causes trouble. And the same might be said in regard to the Tilden valve; I don't so much fear corrosion as I do sediment.

MR. THEODORE H. MCKENZIE. Mr. President, I cannot quite understand how the sediment gets into this pipe when there is no circulation, no water flowing through it.

MR. DANA. In the case I referred to there was a test-pipe at the top of the building which allowed the insurance inspectors to test the system to see if there was water in it. That caused a slight flow about twice a year, and that was what did it.

MR. FREDERICK N. CONNET. In very many of the large mills there is an underwriters' pump, and the pressure that can be obtained by that pump is generally in excess of the city water pressure. The water department, fearing that the impure water pumped by that pump may enter the mains, requires a check-valve between the main and the mill. Now a check-valve being there is not objected to by the insurance companies, and if that check-valve is loaded with a weight and is used in the place of Mr. Tilden's device, you can prevent the water flowing through it, unless the pressure on the two sides of it differs by more than 3 or 4 or 5 pounds or any determined amount. If you place a meter in a by-pass around that check-valve you get very nearly the same conditions that you get with Mr. Tilden's device, and I don't see why that is objectionable, unless there is a chance for the check-valve not to be perfectly seated, and therefore a certain amount of water might get through the check-valve without being

measured. It seems to me that the simplicity of this arrangement commends it.

PRESIDENT BROOKS. I think that everyone who has had much to do with check-valves has regretted very often that they are not more perfect than they are. If there is anything in this world which will give trouble when you do not expect it, it is a check-valve.

MR. CONNET. But, Mr. President, isn't the only trouble which has been found with check-valves due to their not closing?

THE PRESIDENT. Yes, sir.

MR. CONNET. They will open under all conditions, but they may not close, and therefore I do not see why the insurance companies should object to them.

MR. F. H. CRANDALL. As I understand it, Mr. President, what we are looking for is not something which will satisfy the insurance people, but something which will enable us to know how much water is used or wasted on the premises which are supplied through these fire pipes; and the fact that a device will permit, or may be expected to permit, very small streams to pass through it without registration or without warning is sufficient to condemn it. If we were studying to get up something to satisfy the insurance people we would not have do to anything at all, because they are satisfied where there is nothing. It is a fact that the water departments and the communities generally are becoming dissatisfied with the abuse of privileges which have been granted, or with the neglect to properly care for favors that have been conceded, and that is what has brought about this investigation and discussion. The check-valve has been thoroughly tried and found wanting.

Twenty-three years ago good mechanical engineers saw in " the packed stems and complicated moving parts " of the Burlington motor insurmountable obstacles to its safe and satisfactory operation.

Experience with the motor has entirely done away with the misgivings inspired by its formidable appearance, as it will, I have no doubt, with this device.

The meter on such a device would naturally be inspected as often as the other meters on the system, and a department finding

it worth while to install such a device would naturally deem it even more worth while to be assured not only of its correct registration, but also of its preparedness for satisfactory operation under all conditions.

MR. DANA. Mr. President, if this Association cares to go ahead without consulting the interests of the insurance people, it seems to me it would be unwise, for they certainly have rights; and if devices are put in which the insurance people find by tests to be unsatisfactory, their only redress is to raise the rate up to what they consider it is worth, and that I think they will do. They certainly cannot take chances with imperfect devices, and they are surely not making enough money nowadays so they can afford to take unnecessary chances.

MR. LEONARD METCALF. I have listened to Mr. Crandall's description of this device and to this discussion with a great deal of interest. Unfortunately I have not yet had an opportunity to see the device in action. One thing occurs to me, which has been suggested by the discussion, that I might allude to. We all recognize, of course, that there is a great difference in the character of the water which is supplied by different works in different parts of this country. I think it may be said, generally speaking, that the water which we are accustomed to use in this part of the country, in the Northeast, carries fewer solids, — much less sediment, — than the water which we find in many works in the Middle West and in the South, so that we would look for a great deal more trouble from sediment in those regions than we would in this vicinity. It occurred to me as Mr. Dana spoke that the difficulty of the closing up of this small pipe leading to the cylinder could be met either by making that pipe large enough to meet their requirements, or by not only making it larger but also by making it possible for the insurance inspectors to test that pipe by permitting water to flow through it at such times as they visit the mills.

In regard to the cylinder itself, I can conceive of conditions under which I should think it might clog with sediment in the water. However, if the leather cup clogs seriously, I should think that a metal piston might be used, which would be less likely to clog. Large particles, of course, can be screened out by

simple screens. Smaller particles might with a leaky piston be gradually screened out by the piston and allowed to plug, and under those conditions I assume that the piston would not work. But with our waters in the North I should think the chances of that would be very much smaller than in the South and Middle West.

MR. ROBERT J. THOMAS. I will state that on this pipe which leads to the top of the valve there is an arrangement by which the pipe can be opened at will by anybody. There is a valve on it, or plug-cock, by turning which it can be demonstrated at once whether the valve or pipe is clogged or not. That could be easily done by the meter inspector every time he goes there to read the meter.

THAWING FROZEN SERVICE PIPES BY ELECTRICITY.

BY FRANK A. McINNES, ASSISTANT ENGINEER, CITY ENGINEER'S OFFICE, BOSTON, MASS.

[*An Informal Talk at the Meeting of March* 9, 1904.]

Mr. President, — My experience with electric thawing has not been very extended. The method is not new, as it has been tried in the West to a considerable extent. About three weeks ago a friend from Missoula, Mont., told me they were thawing pipes out there by electricity, and I thought it was time for the city of Boston to at least try the experiment. The water commissioner was kind enough to say " Go ahead," so I at once got Mr. Eldon, electrical engineer of the Edison Company, interested, and we went to work.

We have thawed about 20 services; the shortest time taken was three minutes, and the longest about eight minutes, depending upon the strength of the current. We first used the Edison alternating current of 2 250 volts, with a 30 kilowatt transformer and a water rheostat inserted in the primary circuit; the resulting current was approximately 280 amperes at 58 volts. In the secondary circuit an ammeter was used to determine the amperes flowing and a voltmeter to determine the pressure. One of the secondary wires was connected directly to the service pipe inside of the house, the other to a hydrant on the main pipe in the street; in about four minutes water began to trickle, and in a minute or two more there was a free flow. The power actually used on the pipe was about 20 horse-power. In the case of the first two services thawed out, during the operation I had my bare hand on the pipe, and only a slight warming up could be noticed.

We then decided to try less power, and went to work with the Edison direct 220-volt current. In this case we simply connected one end of a wire to one of the outside wires of the Edison system and the other end directly to the service pipe in the house; no further connections were made. A water rheostat in circuit

reduced the pressure to about 20 volts, and about 300 amperes were used. Under these conditions the longest time taken to thaw a service was eight minutes. All services were of lead.

I am satisfied that the practical way would be to have a portable plant, such as a gas engine and dynamo, capable of supplying 8 to 10 horse-power. That would undoubtedly be suitable for the purpose and would be entirely independent of electric light currents, or street railway currents, or anything of the kind, and the electricity could be made as wanted.

THE PRESIDENT. You think it would be perfectly practicable to employ a small gas engine?

MR. MCINNES. That is the only way, sir; otherwise it is necessary to handle a current of high voltage, and you must have a man who knows how to do it. It is rather dangerous work except for an expert. I think it is practicable to have a gas engine and dynamo of 8 to 10 horse-power. We find that a current of 300 amperes and 20 volts produces the desired effect.

THE PRESIDENT. Have you had any experience on main pipes?

MR. MCINNES. I have not, but I do not see why it should not work just the same.

THE PRESIDENT. You think the heating effect in a 6-inch main would be sufficient with that number of amperes?

MR. MCINNES. No, you would have to increase your current, of course, to perhaps 700 or 800 amperes and use higher voltage as well.

THE PRESIDENT. If you were going to equip for thawing a main, you would need a larger apparatus?

MR. MCINNES. For thawing mains, perhaps it would be better to use the Edison or the Boston Elevated current.

THE PRESIDENT. Have you tried it on a hydrant?

MR. MCINNES. No, we haven't. We didn't appreciate the value of the method until the hydrants were thawed out. I don't know why it should not work.

THE PRESIDENT. I think it would be a very fruitful field for some of our electric friends.

MR. MCINNES. Mr. Eldon, of the Edison Company, told me this morning that he was going to get up such an outfit and would advise his company to exploit it, as he thought it would more than pay for itself as an advertisement.

THE PRESIDENT. Well, it would not be an expensive apparatus, as I understand it, Mr. McInnes?

MR. MCINNES. I don't know what the cost would be, but it would exceed a thousand dollars. The plan we adopted was quite inexpensive.

MR. FREEMAN C. COFFIN. I should like to ask whether it is simply a question of more time unless you have a high voltage?

MR. MCINNES. That question I have been considering, and I have supposed it was, but those who watched the last thawing when I was absent say that they do not think so. I think that 7 or 8 horse-power is about as low as you could use, but I am not sure of that.

THE PRESIDENT. I should like to ask whether after a frozen service pipe is thawed it is not necessary to let the water run in order to provide against its freezing up again?

MR. MCINNES. It is necessary. We had that experience as well. We told the people in one house to let the water run, and they said they would let it run for the rest of the winter. On Dorchester Street we thawed out a pipe and advised that the water be let run, but some one inadvertently closed the cock within a minute or so, and in ten minutes it was frozen up again. My orders were to let the water run at least two hours.

MR. F. L. FULLER. Of what material was this service pipe?

MR. MCINNES. It was of lead.

MR. FULLER. Do you think a cement-lined pipe would offer any difficulty?

MR. MCINNES. Well, it would be a different problem. I don't suppose it would work so nicely as in the case of lead, but see no reason it should not be successfully done.

MR. A. E. MARTIN. In Pittsfield they have been thawing pipes in the same way. There, in the first case, they thawed 500 feet of 6-inch main in about five minutes. That can be verified, I am told, by the authorities there. And I also understand that in New Jersey they have had a little experience in thawing water pipes by electricity, having a machine which is mounted on wheels and a dynamo that they cart around the streets and use in that section. I was told that they had 700 frozen service pipes, and that they thawed them out at the rate of 100 a day.

TWO VIEWS OF BOILER USED BY MANCHESTER WATER WORKS.

A PORTABLE BOILER FOR USE IN THAWING FROZEN PIPES, ETC.

BY CHARLES K. WALKER, SUPERINTENDENT OF WATER WORKS, MANCHESTER, N. H.

[*Presented March* 9, 1904.]

The accompanying photographs, Plate I, show a portable boiler which I have used for thawing the ground and frozen service pipes during the past winter and which has already paid for itself; it is also suitable for pumping water from a trench, for running a steam drill, or for other purposes.

The machine consists of a vertical boiler mounted in an iron frame with iron axles, with four wheels, arranged to be drawn by one or two horses.

The boiler is of ample capacity to furnish steam for the required purpose; it is 27 inches outside diameter, 46 inches in length, with 121 1½-inch tubes, 26 inches long. It is covered with asbestos and wood lagging, and sheathed with planished iron. The top is fitted with a suitable smoke stack.

The boiler is fitted with fire door and grates, steam gage, gage cocks, safety valve, and injector. There are also fuel boxes on each side under the back axle. There is a water tank of sufficient capacity to furnish the water required for the boiler.

Arrangement is made for seat for the driver, with tool box underneath. The machine is also supplied with steam valves and connection to the hose for thawing out purposes; also, one 2-inch and one ¾-inch ejector, with suitable suction hose and foot valve for lifting water out of trenches when required.

The total weight of the machine in running order is about 3 435 pounds.

THE LIFE OF CAST-IRON PIPE.

CONTRIBUTED BY MR. C. CAVALLIER, DIRECTOR OF THE FOUNDRIES OF PONT-A-MOUSSON, FRANCE.

During the construction of the Metropolitan Underground Railway of Paris, it became necessary to remove one of the mains of the Vanne water supply, which, unlike many of the pipes of Paris water works, was laid in the ground, and occupied exactly the location required for the subway, for a distance of 1 200 meters ($\frac{3}{4}$ mile) along the Boulevard St. Jacques. This main was laid in 1874, and consisted of cast-iron pipes with bell and spigot joints, 800 millimeters (32 inches) in diameter, in lengths of 4 meters (13 feet). The disjointing was accomplished by cutting out the lead with chisels, after which the pipes were easily separated, the loss from breakage of pipes being only about 2 per cent.

All of the pipes had an interior coating of scale about 6 or 7 millimeters ($\frac{1}{4}$ inch) thick, which was easily detached with the hammer. The iron thus laid bare was in a perfect condition of preservation. Much of the coal-tar coating was still intact, and the numbers and weights marked in white lead were as clear as though just applied. The exterior of the pipes was also in good condition. The coating still remained on the greater part of the surface, while the balance had undergone a slight superficial oxidation. Remembering that these observations apply to pipes which had been in service, in the ground, for about twenty-eight years, after which they were in nearly as good condition as when laid, it is easily seen how safe and economical is the use of cast-iron pipes.

A still more convincing fact has recently been observed. The city of Paris, requiring the land occupied by the Chaillot pumping station in Place de l'Alma, has discontinued that station. This was the first station erected for supplying Paris with water. The intake consisted of flanged cast-iron pipes extending out into

the Seine, and, as it was no longer of any use, it has been taken up from the river bed.

The condition of these pipes after so long a period of immersion is a matter of considerable interest. They were in so good a state of preservation that they could have been relaid, but, as they were of antique type, they have been broken up and remelted. After removing the scale and the shellfish which had accumulated upon the exterior, the words " Creusot, an 10," in raised letters, could be easily read. This date corresponds to the year 1802 of our calendar.

The metal was a gray cast iron of excellent quality, the fractures of which were as sharp as of a piece just from the foundry. No alteration of either interior or exterior appeared after more than a century of submergence in the river.

Such a proof of the durability of cast iron requires no comments, but is certain to impress deeply all who are interested in the construction of permanent conduits for water.

NOTE ON OLD WATER PIPE SYSTEMS IN FRANCE.

Versailles, Marly, Meudon, and St. Cloud.

According to the Ministry of Public Instruction and Art, the conduits which supply the water to the great fountains in the park of Versailles are of cast iron, and date from the same period as the park itself. The most important are as follows:

Three pipes, 500 millimeters (20 inches) in diameter, 3 000 meters (10 000 feet) long, which bring the water from the Park of the Trappists to the reservoirs of Montbauron.

Two pipes, 500 millimeters in diameter and 2 250 meters (7 500 ft.) long, and 3 pipes 325 millimeters (13½ inches) in diameter and 1 500 meters (5 000 ft.) long, which convey the water from the reservoirs of Montbauron to the principal gate house.

Two pipes, 500 millimeters in diameter and 3 000 meters (10 000 ft.) long, and 1 pipe 325 millimeters in diameter and 1 500 meters (5 000 ft.) long, which bring water from the reservoirs of Gobert to the reservoirs of l'Aile.

All of these pipes were laid in 1685, or 219 *years ago*. The con-

duit of Chevreloup, from the reservoir of l'Aile to the Trianon, 325 millimeters in diameter and 3 500 meters (11 500 ft.) long, was laid in 1687, or 217 *years ago*.

Several old pipes of various diameters for conveying water from the reservoirs of Picardie to those of Montbauron, for distribution within the parks and in the town, and the spring-water conduit, having in all a length of about 8 000 meters (26 000 ft.), were laid between 1664 and 1688, or from 216 to 240 *years ago*.

All of these pipe lines consist of pipes one meter in length, joined by means of bolted flanges. They are of considerable weight, and still serve their purpose satisfactorily.

The few repairs which have been required have generally been necessitated by the bad condition of the flange bolts, which have rusted out.

Rheims.

According to Mr. Lamandiere, engineer and superintendent of the Rheims Water Works, the water supply of that town was established in 1748 by Mr. Godinet, canon of the cathedral. This system was in more or less regular service until 1840. At this time a new system, much better constructed, was built and is still in operation, although with considerable modifications and enlargements.

The distribution pipes in Canon Godinot's system were of lead. In building the pumping works some cast-iron pipes of the system built in 1748 were found. These were about 20 centimeters (8 inches) in diameter and 1.20 meters (4 feet) long, with square flanges. These pipes were in good condition when found.

Clermont-Ferrand.

Mr. Dalechamps, engineer and superintendent of public works of Clermont-Ferrand, furnishes the following notes relating to the old cast-iron water pipes of that town:

On December 5, 1730, a meeting of the town council noted that the conduit was considerably damaged. Sixteen years later, on September 14, 1746, the commissioners of fountains made an agreement with the Sieur Marchais, iron merchant of Paris, for

furnishing pipes of cast iron for the fountains. The works were constructed about 1748-49. The conduit, for a length of 1 570 meters (5 150 ft.), consists of 1 555 tubes 5 or 6 inches in diameter and 3 feet long. On the plain where the pressure is greatest the pipes are 9 lines (0.8 inch) in thickness, elsewhere they are 6 lines (0.5 inch) thick.

In 1867 the old conduit was paralleled by cast-iron pipes with lead joints, which was to supplement the old system. This is now out of service at several points.

The pipes were cast horizontally. The flange joints were made with a thick lead gasket, sometimes as much as 23 millimeters ($\frac{7}{8}$ inch) in thickness. The system is under a considerable pressure.

Saint-Etienne.

According to Mr. Andrieu, engineer and superintendent of public works of Saint-Etienne, there are in that city some cast-iron pipes which have been in service since 1782, or for one hundred and twenty-two years.

RATES FOR METERED WATER.

[*Topical Discussion, March 9, 1904.*]

Mr. FREEMAN C. COFFIN.* I suppose I am assigned to open this discussion because I am one of the members of the committee recently appointed by this Association to consider the rates for metered water. This committee as yet has done but little. We have had two meetings and discussed the matter somewhat. Whether we shall be able to do anything worth while remains to be seen. It is an important subject, and there are a great many sides to it. I think most of us believe that the extended use of meters, and perhaps the universal use of meters, is desirable and inevitable. Many of us consider the use of meters as a means of water-waste prevention rather than a matter of raising or securing revenue from water works. The prevention of the waste of water seems to be the most important function of meters.

There are used in different places from 20 gallons per capita to — well, it is difficult to say — perhaps 300 gallons of water per capita daily. There is a legitimate difference in the use of water. Some places use legitimately twice as much, perhaps three times as much, as other places. The per capita consumption tends to increase with the increase of population, due to the various uses of water that occur in a large place in excess of those in a small place. The larger the place, the more extended the use of water. Some communities actually use a large amount of water for manufacturing purposes. Generally speaking, however, large consumption, exceeding from 40 to 75 gallons per capita daily, is due to waste and not to use. In an ordinary town or city the actual use of water will probably not exceed from 30 to 60 gallons, or possibly, in extreme cases, 75 gallons per capita per day.

Some meters are used in all places to measure the water of large users, but regarding the meter as a means of preventing

* Civil Engineer, Boston, Mass.

the waste of water, a community or water department when considering the general adoption of meters finds that one of the most important points to be considered is the effect of meters upon the revenue. A certain amount of revenue must be raised, and what is not received from the consumers must be raised by taxation. There is, of course, a difference of opinion in regard to the amount or proportion that should be raised by revenue and by taxation. That question is not the subject of discussion to-day, but when the amount is once determined that shall be raised by rates from the consumer, then upon the adoption of meters it is desirable that the revenues shall not become less than that amount; that is, there shall not be any deficiency. This has nothing to do, of course, with the question whether rates are high or low. That is another question, but certainly if meters are adopted, the revenue must be kept up. I don't know that there is any concensus of opinion in regard to what effect the adoption of meters will have upon the revenue. When rates are arranged upon a fixture basis, arbitrary and unscientific as it usually is, we know approximately what the revenue will be; but if we adopt meters, a change is made which may increase or decrease the revenue, and it is difficult to determine which.

Now, the question comes, How shall the revenue be raised, and how shall the meters be applied? Shall we endeavor to use meters upon all services, even those with one faucet only, or leave out the services with one faucet and apply meters only to services with more than one faucet? In many cases the minimum meter rate is fixed at $10 a year. That, of course, shuts out single faucets in communities where the single faucet rates are about $6. Now, a single faucet, under some conditions, causes a great deal of waste. Take a house where the pipe is not well protected from frost, and we all know that the waste caused by letting the water run to prevent freezing is very serious. It seems to me that, if possible, meter rates should be so arranged that meters can be placed upon single faucets. On the other hand, if we place the minimum rate at $5 or $6, in order to meter single faucets, houses with bath tubs, water closets, and set tubs, and all the appliances of modern comfort and luxury in the use of water, will pay their

$5 or $6, and, if they are very frugal, they will perhaps pay no more. The chances are they will not pay the $14, $15, $18, or $20 they are now paying.

The question is whether it is not perfectly reasonable and just, that without regard to the amount of water they use, houses having all these conveniences for the use of water should pay a larger amount than houses of only one faucet. It seems to me that it is. The water works are built at great expense to provide those things, and, to a certain extent, the greater the convenience and luxury derived from the water works, the greater the payment should be. That may not be possible under the minimum rate that admits of metering a single faucet.

Now there is a class of towns, of which we have a good many examples in Massachusetts, where there is a permanent population as distinguished from a transient population. The transients use more water in proportion while in town than the other people. In summer places, so-called, the consumption tends to be very large. If you have meters with a minimum rate of $5 or $10, whatever it may be, those people are rarely going to pay any excess, unless the excess is charged quarterly, because they are there only two or three months. Now, it may be said that a man who uses water only in the summer should not be charged so much as the man who uses it the year round, but that is not true; it costs just as much to supply a consumer with water for one month as it does for twelve months. The supply has to be as large, especially if the use of the water is in the summer, at the time when the supply is lowest; the piping must be just as large, the pumps and the reservoirs must be as large, and there is no difference in the fixed charges. We all know the fixed charges of a water system constitute the principal item of cost. If we include with fixed charges the salaries and operating expenses, which are not variable, the only cost that varies with the consumption is the cost of coal. The difference in coal for pumping is comparatively small, whether a man uses water in the summer only or in the winter as well. In some of these places the use of meters would reduce the tremendous waste of water that goes on. I have one place in mind where the daily consumption is about 300 gallons per capita in the summer time, based upon

the actual number of people there, not the permanent population. I know of another place of not over 2 500 people which uses 250 gallons per capita. This excessive use of water certainly requires the use of meters.

I believe that we all admit that the use of meters is the only practical means of restricting the waste. It can be restricted by a careful and persistent inspection, but that means a good deal of money, and it means much persistence, more than is usually devoted to it, and, in spite of inspection, waste will continue. It is, I think, fair to say that meters are the only practical way of restricting the waste of water. These places that I speak of require meters, but how can the rates be fixed? Although a very large amount of water is used in the summer for two or three months, the entire amount used in the year is small, and the revenue received at usual meter rates will not meet the expense of maintaining large works the year through in order to supply water for a few months. That is one of the serious problems of arranging meter rates.

Now, the question of the effect on the revenue, the question of the class of services which can be metered, and the question of the class of communities in which the meters shall be applied, — all these must be considered. As I have already stated, the committee which has been appointed by this Association has done very little as yet. It has sent out some blanks, and has received a great many replies. On the blanks were two questions in regard to receipts. One was whether a house with full plumbing under metered service in the particular town under consideration brought in a greater or less revenue than without meters. Most of the answers to this question indicate that the receipts are generally less.

Another question was, Is the total net revenue greater or less? The answers examined seem to show that it is less.

Now, I have taken the figures from the reports of Reading, Mass., and have made a diagram that shows the results graphically. This diagram (Fig. 1) shows what I am trying to indicate, namely, that upon the general introduction of meters the revenue decreases. The diagram covers the period from 1891 to 1903. It will be seen that the increase in the number of services is

quite uniform, and that the increase in revenue was quite rapid until 1887, at which time there were 20 per cent. of the services metered. During the next year the metered services were increased to 93 per cent., and the revenue fell from about $8 150 to $6 400, or more than 20 per cent. It began to rise again, the

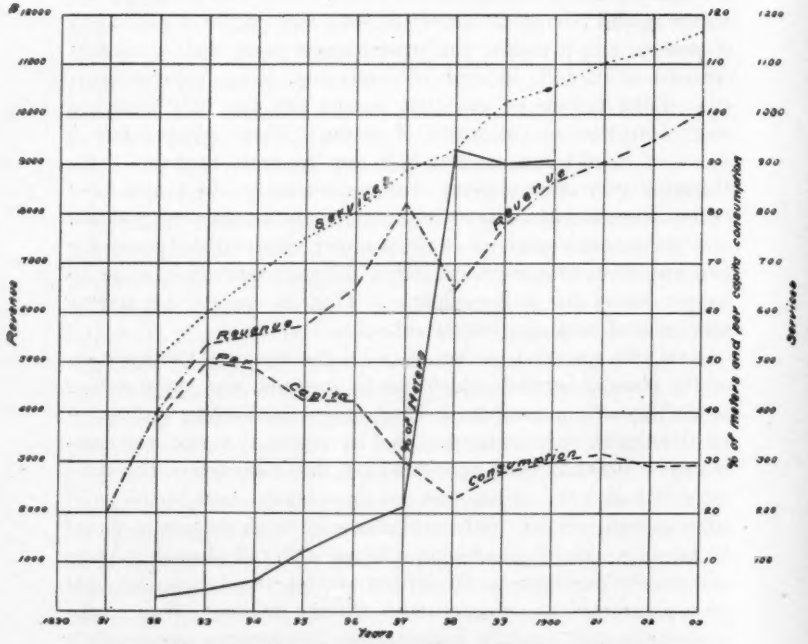


DIAGRAM SHOWING THE EFFECT OF METERS IN READING MASSACHUSETTS

FIG. 1.

next year, but it was nearly three years before it was equal to that of 1887.

The diagram shows clearly the tendency of the revenue to decrease with a general installation of meters.

The committee on metered rates is not responsible for anything I say here, as I am only speaking as an individual. I want,

however, to make a certain suggestion as to a possible method of fixing meter rates, because I should like to have some discussion on it and see whether it is considered feasible, or whether it has been tried, and what the attitude of the Association would be towards it. I shall probably suggest this method to the committee for consideration: Take the case of established works, with a revenue based upon fixture rates when the adoption of meters is being considered; it may be done in the way I suggest and avoid a possible reduction of revenue and also cover some of the other points that I have raised. The suggestion is that the fixture rates in use be continued without change; the meter to be used simply as a means to check the waste. That will leave practically the same revenue which they have been receiving, except where there is an excess used. It might be wise to make a reduction in the fixture rates of 5 or 10 per cent. as an inducement to the consumers in the adoption of meters. Under my suggestion it is assumed that the department will own the meters, and make no charge for rent; it might or might not require a deposit. Then put on meters wherever the consumers desire them, or wherever the department desires them, — it should, of course, be at the option of the department where the meters are to be placed, — and read them quarterly. Now, each consumer shall have the right to use without excess payment an amount of water which at the meter rates will correspond to the sum he pays; that is, if he has one faucet, and he pays $6 for the water, he may use each quarter $1.50 worth of water without further payment, but if he uses any more than that in any quarter, he will pay for the excess. The bill perhaps would not be collected in that quarter, but that would be a matter of detail. The rates may be collected as now. If collected in advance, the fixture rate would be paid, and if an excess is used, that might be paid for each quarter or at the end of the year.

The meter rate may be arbitrary, as now, or based upon the cost of supplying the water. In the latter case the price, of course, would differ in different places, and in some places a consumer would get more water for his fixture rates than he would in others; that depends largely on natural conditions. This is about all there is to the suggestion. It is simply a device

to avoid some of the difficulties that are met in adopting meters. In case of towns that have a large summer population, the consumers would pay their fixture rates, and if they came in the summer and used a large amount of water, they would pay for the excess water they used in that quarter.

There may be a great many objections. I am making this suggestion in ignorance, and I hope it will be discussed; it may be of some use and it may be of no use. At any rate, it would, I believe, cover the case of summer places, and it would, above all, determine in advance something like what the revenue would be, and it would be effective in reducing the waste of water, which is what we are really after in the metered system.

I hope the other members of the committee will have something to say from their standpoints. As I have already said, this is what I have to offer individually, and what, to a certain extent, I may offer to the committee later.

MR. H. V. MACKSEY.* Before we can hope to offer anything to be generally adopted, it would be well if we can find out the view taken by the members of the Water Works Association. I have been unable to learn whether a water works is supposed to be a public service corporation or an eleemosynary institution.

If we discuss the subjects of rates with men who represent certain cities and towns, and ask them why they are serving water at different prices to different classes, they argue that it is not fair to charge all alike. The wealthy man who owns a residence with high valuation, they say, can afford to pay more than a man who lives in a little shack and has but a single tap. Yet in some towns and cities where they adopt this method of assessing rates, when the wealthy man's property reaches a certain valuation, they cease to base assessment on that valuation. There is a maximum valuation, and they consider one man too wealthy to tax and one too poor to tax, and it is the unfortunate middle class which gets ground in between their two systems.

My personal opinion is that water as supplied by cities, towns, or public service corporations should be supplied at the same price per quantity to all takers, and that if it is necessary to take care of the poor, it should be done directly and openly

* Deputy Superintendent of Streets, Boston, Mass.

through general taxation and not by an institution that is supposed to be run on a business basis.

We find also another objection. We are told that if we put meters on all services and compel the large manufacturer to pay at the same rate for water that the small taker does, we shall drive the large manufacturer out of that town, and consequently many of the residents will be put out of employment, and we are told that other towns and cities will take that factory, giving it land and taxes free. If cities and towns wish to do that, very well, but they should not charge this tax up to the small water taker.

I think the proper way to sell water is to sell it at a uniform rate, making that rate as low as possible, and meter every service. Yet I cannot find many who agree with me. The scheme laid down by Mr. Coffin is practical. The only weak feature we can see at present is that we must find money to cover first cost, inspection, and maintenance of meters. That money must be provided in some way, and if you tell a water taker that he must pay that expense, he opposes meters as an expensive luxury. If you ask a city or town to supply the money from general tax levy, they ask you to earn it all. This scheme proposed a reduction in rates. In the meantime, you must have money to buy and install meters.

There was another scheme proposed by a member of the committee, whom I do not see present, that there should be a service rate, every service being metered; a certain fixed charge for each rate of service, including meter, should be made, and a uniform rate for water in addition. That seems to be approved by a number of persons with whom I have talked. That scheme seems feasible in very many cases. The only difficulty is the provision of money to establish meter service.

Eventually we will reach a point where we must install meters and sell water at a uniformly fair rate to all. Takers will not stand different rates on metered water any more than they will on metered gas. We must get down to a basis where we treat every one alike. If it is a temporary expedient to get meters started on the plea of waste and not service, I think the plan laid down by Mr. Coffin very good and feasible.

MR. CALEB M. SAVILLE.* I think the subject has been well gone over by others, and especially so by Mr. Coffin. The scheme which Mr. Macksey has just spoken of may be worthy of consideration, but I do not think it is anything more than a suggestion. Perhaps it is well that it is given here, and then leave it open for discussion.

I have outlined a method which I should like to have considered by the members.

When changing from a fixture to a meter system of assessing water rates, it is undoubtedly desirable to make as little disturbance as possible in the existing rates.

Most rate payers expect a reduction in the water bill after a meter has been installed, and are sure that the meter is incorrectly registering if they are disappointed. In some places a handsome profit is obtained yearly from the conduct of the water works, but in most municipal works the rates are so low as hardly to pay all the demands upon them. In such cases it is hard to see how a still further reduction can be made and yet have the works self-supporting. In many cases undoubtedly this could be done if the works were run on the economical basis they would be if under private management.

The items of construction and extension, belonging wholly to new work and constituting additions to the plant, it is not necessary to consider here, as it is generally conceded that they may equitably be met by bond issue and become a charge on future generations. If this be granted, the principal items of expense to be met yearly are:

(1) Office expenses, meter reading, maintenance, and renewals.

(2) Interest on bonded debt.

(3) Payment to sinking fund.

(4) Pumping and other costs directly affected by quantity of water used.

There seems to be no question that the present practice of fixture rates is illogical and has no basis for consideration at this time, when means for accurately and cheaply measuring water are at hand.

After a service is installed it is just as much work to maintain

* Division Engineer, Metropolitan Water Works, Boston, Mass.

it, whether it passes ten cubic feet a day or one thousand, with the exception that the investment and repair in the case of the larger meter is somewhat greater than in the smaller ones. This item could be adjusted readily in the scheme outlined below. On account, therefore, of the nature of the charges in Item 1, it seems equitable that they should be divided equally among all services (excepting as modified by size of meter). The other three items are governed in more or less degree by the quantity of water required, and therefore might be charged for at a flat rate per 1 000 gallons or per 100 cubic feet.

In brief, the proposed agreement would consist of two parts:

(1) Expense for office, meter reading, maintenance, and renewals divided by the total number of service connections, this to be a fixed charge for every service.

(2) Expense for pumping, interest on bonds, and payment to sinking fund divided by the net amount of water supplied to the town or city (*i. e.*, total of the service meters, assuming that all services are metered), each rate payer to be charged at this rate for the quantity of water registered on his meter.

The above plan would avoid all expense for survey of premises to determine a rate, and no readjustment would be necessary if new fixtures were added or old ones abandoned. Each consumer would be treated exactly as every other, and only such water as was actually used would be paid for.

Under this system (no minimum rate and no allowance of water) it would not be necessary to collect rates quarterly in order to forestall the saving of water for summer use, as is frequently done under minimum rate payment, because all water used would be paid for. This would be a considerable saving in clerical expense, as only bills to large consumers under this plan would need to be rendered quarterly. Rates should be payable in advance, with an adjustment at the end of the year, a discount, perhaps, given for prompt payment, and a fine for those who are dilatory. No rebate should be given except for incorrect registration by the meter, which should be owned by the water department. A flat rate should be paid for all water used, from the least to the greatest amount, — the nature of the use and the benefit obtained from the supply offsetting the

advantages supposed to accrue from the sale of large quantities to a single consumer.

In a town or city contemplating a change from fixture to meter rates, under this plan the present expenses would be taken as a basis, and the rate per thousand gallons adjusted to return a sufficient revenue. The cost of meter installation should properly be charged to construction or extension, and be met out of the proceeds of the bond issue.

All water should be paid for just as any other commodity, and no distinction made. If it seem best to make certain classes of property bear a greater share of the cost, a portion of the expense, as payment to sinking fund or interest on debt, might be assessed either on street frontage or real estate valuation. This would seem just, as the convenience and luxury undoubtedly are of value, and should be paid for by the consumer. If a portion of the rates be so assessed, the difficulty experienced with the single faucet payer will be overcome, and he, too, will pay only for the water used.

By assessing a portion of the rates on frontage or valuation, the summer resident would have to pay his full share toward the conduct of the works. The yearly cost of maintenance of the system for the few months he uses the water then would be met by the fixed charge, the water would be paid for in proportion to the quantity used, while the advantages incidental to a full supply of water would be met by the real estate amount.

Mr. C. R. Felton.* There is one thing in relation to Mr. Coffin's diagram which strikes me forcibly — he shows a decided decrease in revenue. If the people get just as good service and use just as much water as they need under the meter system, it must be conceded that while the city or town may have lost through the decrease in revenue, it was certainly saved to the people who pay the water bills.

In addition to this, in the case of a city or town nearing the limit of its supply, if interest and sinking fund on a new supply for several years could be saved, it might make a very different showing so far as net revenue is concerned.

* City Engineer, Brockton, Mass.

In the case of our own system, had we used anywhere near the amount of water used in other cities, we should have had to secure a new supply ten or fifteen years ago.

The following table shows the consumption of water in Brockton since 1892, which was the first year that records were available, the pumping plant being installed at that time:

Year.	Population.	Total Consumption (gallons).	Daily Consumption in gallons per capita.	Domestic use in gals. per capita.		Manufacturing (gals. per capita).	Street sprinkling (gallons per capita).	Fountains (gals. per capita).	Unaccounted for (gallons per capita).
				Metered	Un-Metered				
1892	29 643	271 652 000	25.0	—	—	—	—	—	—
1893	30 817	264 409 000	23.5	—	—	—	—	—	—
1894	31 993	323 201 000	27.7	6.7	3.8	—	—	—	—
1895	33 165	399 694 000	33.0	7.3	3.2	2.4	1.8	1.5	16.8
1896	34 544	403 882 000	32.0	9.2	3.3	3.2	2.2	1.4	12.7
1897	35 923	386 428 000	29.5	8.5	2.6	4.0	2.8	1.4	10.2
1898	37 302	369 370 000	27.1	10.3	2.8	2.7	2.2	1.3	7.8
1899	38 681	414 737 000	29.4	11.0	2.7	3.6	2.6	1.3	8.2
1900	40 063	429 002 000	29.3	10.9	2.5	4.0	2.5	1.3	8.1
1901	41 610	447 500 000	29.4	11.5	2.1	4.0	2.4	1.4	8.0
1902	43 159	506 800 000	32.2	12.8	1.4	4.2	2.2	1.6	10.0
1903	44 704	537 800 000	33.0	13.5	1.7	4.9	2.1	1.6	9.2

We have about 90 per cent. of our services metered, and our consumption for the last ten years has not exceeded 33 gallons per capita daily. I should say that perhaps 90 per cent. of the population are consumers. Up to 1892 we had no system of sewers. It has always been argued that as soon as you get a system of sewers, the water consumption is going to materially increase. The first years that we had any sewers the water consumption rose to about 33 gallons per capita, and we ascribed it more or less to the new sewers, but the next year it went back to 32 gallons, and the next year after that to 27 gallons, and we have never had a consumption of over 30 gallons per capita since that time until within a year or two. We now have a daily consumption of about 33 gallons per capita, but of this there are about 8 gallons which we cannot account for, and, in my opinion, it is due to leakage from the system through services and mains.

I agree with what a previous speaker has said, I think there should be a flat rate for metered water,— that every one should pay the same amount for water used, but we do not do it that way; the usual rate of 30 cents per thousand gallons is decreased for large users, and the manufacturers have a maximum rate of 25 cents per thousand gallons and a minimum rate of 15 cents per thousand gallons.

Mr. Frank E. Merrill.* Mr. President, I think Mr. Coffin's paper and Mr. Macksey's remarks have covered the subject matter which has been before the committee so thoroughly that I don't know that I have anything to add on that topic. I agree very largely with the statements made by those gentlemen with the conditions that they bring up.

The meter system in Somerville is in its infancy. I think we are alive there to the importance and the advantages of such a system, but we have not as yet acquired very much experience, as our domestic meters have been in operation hardly a year.

I am one of those who agree with my friend Macksey in believing that the rate should be a flat rate, and should be made as low as possible. I always felt that it was a discrimination against householders — whom the water supply of a city is supposed to primarily benefit — to charge them for the small amount which they require a larger price than is charged to manufacturers for the use of water in their business, and I am pleased to say that we have this year in Somerville changed our basis of assessing rates from the graded scale to practically a flat rate. The old rate was 14 cents per 100 for the first 20 000 cubic feet used in a quarter, 13 cents for the next 20 000, 12 cents for the next 960 000, and 8 cents for quantities above that. Our rate now, since the first of January, is 12 cents per 100 cubic feet for all quantities less than 1 000 000 cubic feet used in a quarter, which covers practically everything in our city, as we have but two or three customers who use larger quantities than that.

I think in another year, Mr. President, I shall have acquired some experience, and may have something of greater interest to offer to the members of the Association than I have to-day.

* Water Commissioner, Somerville, Mass.

MR. ANDREW D. FULLER.* Mr. President, I think it is the duty of a town to introduce meters for the purpose of establishing, as Mr. Macksey said, a method of giving each consumer the water for which he pays. I have had occasion to see the waste of water, especially from the tap end of the system. If the plant is well constructed and in repair, the real waste is caused by the public, and I think it is to the public only that you can look to stop the waste. I have found that there is a large difference in houses of the same class in the per capita consumption, and this applies not only to the expensive houses, the houses of the rich, as you might say, but also to the houses of the middle class. I will give two illustrations which occurred last summer. One was in a house where the consumption was 11 000 gallons a day. The consumption was far too large even for that house. On investigating the conditions, I found there was an actual leakage through the house of 6 000 gallons a day. I am very certain that would never have been found if the man had not had a meter and had not been obliged to pay on the metered rate. He said it was on account of the excessive water bill that he caused an investigation to be made. Now take a house of another class, where the house consumption was never over 200 or 250 gallons a day; the hose in one hour ran 600 gallons.

I think we all appreciate green lawns, but to any one who has examined the various lawns it is perfectly apparent that there is a great waste there. By continually watering the lawns the ground gets very moist, it is easily dried in the sun, and the roots come to the surface, so that to keep the lawn green it is necessary to continue excessive watering. If the man had had to pay by the meter, he would have shut off the hose on the time limit fixed by the town; you know that depends on the inspectors.

There is another duty which we have to perform, and that is from the sanitary standpoint and also from the question of comfort. It is true that the fixtures in the house are not multiplied as much as they would be if a man was paying on a metered rate for the water that he used. It is true that with the multiplication of fixtures the use of water increases in the house,

* Civil Engineer, Boston, Mass.

but the increase is not proportional to the increase in fixtures. This is something which, from a sanitary point of view, should be encouraged, that is, make it as convenient as possible to use the water for washing and domestic purposes. From the other side, I think, as we have accepted the ordinary rule of assessment, a man should pay according to the benefits received. It is only fair that he should do so.

Mr. William Paul Gerhard.* Mr. President, I am not prepared to say much on this question. I am not connected with water works directly. However, I have a great deal to do with the installation of water pipes in houses, and I would say that in New York City, in new buildings of large size and also in many private houses, with which I have largely to do, we always set a meter, and the cost of the meter is paid by the owner. We do not find any difficulty; the owners don't seem to object to it at all. I have no doubt that the results attained are beneficial in checking waste, and we find very little complaint from the owners in regard to exorbitant bills.

Talking about fixture rates, I might, perhaps, in connection with that, relate a peculiar experience which I have had. About twelve years ago I moved to Brooklyn, now consolidated with New York, and in my small house I had one bathroom with three fixtures. The rates were by frontage and by the number of stories, a fixed rate, and in addition for each fixture after the first, they charged a fixed sum per year; that is, for a bath tub more than the first bath tub, they charged a fixed sum. I got it into my head to try in my bath room a little fixture — it is called a bidet. It is a small vessel which you can use for a foot bath or other purposes, and it uses not more than a gallon or so of water. The water inspector came there, and when the next bill came around, I was charged for two bath tubs. I went to the water department and mildly objected. I argued that if I really had two bath tubs in my house, as the bill claimed, certainly two people should be able to take a bath at the same time, that is, that there would have to be two different bath rooms, which was not the case, and I explained the character of this little fixture, but for year after year I have paid for two bath

* Consulting Engineer, New York City.

tubs, although I have but one in my house. I might add that since Brooklyn was consolidated with New York this has been changed, and the bidet is not now charged for.

MR. JOHN C. CHASE.* Mr. President, my voice has been heard here so often in favor of the general use of water meters, that I hardly think that I can add anything new on this well-threshed subject.

The gentleman who spoke a few minutes ago said he was in favor of water meters because a man then got what he paid for. I am of the opinion that the average non-metered consumer generally gets a good deal more than he pays for, or would use if he had to pay by the quantity instead of by fixture, and that the main object of the meter is to insure the supplying agency getting paid for the water used. The equitable adjustment of the water tax is also an important function of the meter.

I happen to be officially connected with two water supply companies. With one I had nothing to do with its inception or the establishing of the rates and regulations. Meters are not sanctioned except where the water is used for manufacturing or commercial purposes. I am certain that a general use of meters would have saved us quite an expenditure of money in increasing our supply, and our receipts would be more equitably derived from the consumers. In the other concern with which I am connected, meters were put in use to quite an extent when the works were first started, over twenty years ago. We began with furnishing the meter free to the consumer, except for a fixed charge of $2.50 for setting and boxing, which was a very radical departure for a water company, or for a municipality, for that matter. A fixture rate was provided for dwelling houses where it might be reasonably assumed that the legitimate use of water would have a fairly close relation to the number of fixtures and the size of the family. All other consumers were required to have meters, and any consumer could have a meter provided a minimum rate of $10 per year would be paid. The result is that practically all consumers whose fixture rate would be more than $10 per year elect to have meters, and about 70 per cent. of the services are metered. The general price for

* Civil Engineer, Derry, N. H.

metered water is 20 cents per thousand gallons, and one year the metered water averaged a higher price than that, on account of the large number of consumers whose use did not amount to that allowed for the minimum charge. At the same time the unmetered water only brought us an average price of 6 cents per thousand gallons, after a liberal deduction for the estimated quantity used for fires, leakage, and slip of the pumps. As the cost of the water delivered to the consumer was some 8 cents per thousand gallons, it will be seen that the unmetered water was being sold for less than cost, while the metered supply footed the bills.

I am a firm believer in the meter being owned by the water department, whether public or private. It can then be inspected and repaired at the option of the owner, with much less chance for friction or complaint. It is virtually done at the expense of the consumer in any event, as he pays for it in an increased tax levy if a municipality owns the works and in a higher price for the water if it is a water company; and if it is an indirect charge, it attracts much less attention. Personal experience upholds the opinion expressed. Our meters are watched closely, and when a decreasing registration is indicated, the meter is removed, and the necessary repairs made to bring it up to its original efficiency.

The question of rates is largely of local application, and no hard-and-fast rule can be made that will apply to all places. It goes without saying that the average domestic consumer can afford to pay a higher price per thousand gallons than the manufacturing or commercial consumer. At least the domestic taker cannot easily get his supply from any other source, while the manufacturer may quite likely avail himself of a supply that would not be suitable for domestic use, and at a price much lower than the water company would be justified in accepting.

I am inclined to believe that the same meter rate should be charged for all commercial or manufacturing purposes without reference to the individual consumption, making a distinction of class rather than quantity. I may also say that it is plainly evident that the meter has come to stay, and that a generation hence its non-use will be as rare as its use when my attention was first

drawn to the subject some thirty years ago. I am not prepared to advocate their use on services with a single faucet for domestic use, as the expense of maintenance of a meter is too large a proportion of the gross receipts, and a reasonable inspection service will reduce the probable waste to a minimum. They could be applied, however, in such cases, whenever it was thought best to correct any abuse of the single fixture privilege. The general use of meters will come as the result of educating the public up to the point that it is the only equitable way of apportioning the rate and preventing an abuse of privilege.

Mr. Julius C. Gilbert.* Mr. President, I am a believer in meters; still, I think I should hardly believe in metering all the faucets in a country town. We have in my town between 1 000 and 1 100 services, and 50 per cent. of them are metered. If we undertook to make a flat rate for water for every one, I think we should get into trouble. We charge 30 cents per 1 000 gallons, provided a consumer does not use over 1 000 gallons per day. If he uses over 1 000 gallons per day, he has it for 25 cents per 1 000 gallons; if over 2 000 gallons, 20 cents; and if over 3 000 gallons, 15 cents per 1 000 gallons. Some years ago we had the New York, New Haven & Hartford R. R. as a customer. They thought they ought to have their water — they used a large quantity — for 12 cents per 1 000 gallons, and we refused to allow them to have it at that price. Consequently, they laid pipes to a small meadow pond and we lost them as a customer, which took away something like $1 000 per year of revenue. We also have quite a number of large shoe factories. Some of them wanted water at a cheaper rate, and we refused to give it to them for less than 15 cents, and they drove wells and are pumping their own water. By not reducing the rate to them we lost something like one quarter of our revenue.

It seems to me that if you undertook to make a flat rate in any country town, it would work just the same as in other towns as it did in ours if you refuse to cut the rates to large consumers. There are many places in town where it would not be profitable for us to meter the water. I have in mind one block in particular where there are a great many offices and stores and

* Treasurer Whitman (Mass.) Water Works.

fixtures of different kinds, washbowls and water closets, which we have had the good luck not to be asked to meter. In such a block as that, you all know, if a man has an office, that really he would not use $3 worth of water a year, or even perhaps more than a quarter of that, while we get $6 for each one of those faucets all through the block.

In another instance we had a double tenement house which was paying us from $12 to $20 a year, and we put in a meter and now we only get $6 for the water. And, by the way, we charge them 39 cents per quarter for a common five-eighths inch meter. From these double tenement houses in our town we only get about $6 for both tenements, for the reason that they are occupied by, perhaps, a man and his wife, both of whom work in the shop, and the amount of water they use is very small indeed. We have a number of those cases where it reduces our revenue very much to put in meters. Still, as our supply was very short, we have put them in, and we shall continue to do so.

We have in the past two years put in meters on all the new houses that have been built, because they all have bath tubs and water closets, and, of course, they don't want to pay the faucet rates.

It seems to me there is a great difference in towns. We could hardly make a rate which would be applicable to all the towns in New England. Whatever this Association might decide upon as a proper rate, most towns would feel that they should be governed more by the local conditions than by anything that this Association might do. I like the idea of Mr. Coffin, but still I hardly think it would be applicable to all places. I only wish that we could all have a water supply that we could get by gravity, and then we would get a good income and we could please all the people. I am troubled a great deal with complaints about the water bills. If a man has a little larger bill one quarter than usual, he thinks he knows a great deal more about the amount of water he is using than we do when we read the meter. I have often told them that I don't see any use in having meters if a man who had water in his house could tell every quarter just how much he used.

Now, another thing which affects the consumption of water a

great deal is the use of water on lawns. Our works have been in about twenty years; the first few years everybody flooded the lawns — you could see water running down the street everywhere, nights and mornings. Then we passed a vote in town meeting that hose should be used only two hours per day, at night, and before eight o'clock. We did the best we could, but I found the hose all running at eleven and twelve o'clock at night, and they all thought they were smart to do it. You all know how that is. We have many good men in the town, but they will get all the water they can for nothing. I guess that is about so everywhere. I am inclined to think that the only right way is to meter water, but still I think that if a man uses a great quantity, we have got to let him have it at a less rate than a man who does not use more than $5 or $6 worth.

Mr. John O. Hall.* Mr. President, this matter is of vital importance to the water-works man. It seems to me that every one who has spoken has rehearsed the difficulties under which he has labored, and yet not one has touched the keynote of the whole difficulty. The duty resting upon water men, upon public servants, is to administer their affairs for the interest, the profit, and the welfare of the entire community. The whole difficulty, as it seems to me, is that they are confusing the method of administration. I believe in Massachusetts the question presents itself in this way: The community pays for the establishment of the plant. The cost of the establishment should go into the general tax levy, and in that way it is divided fairly. The vacant land in any community is enhanced in value by the establishment and maintenance of a good water plant. Then the men with large properties, or the corporations with valuable plants, pay their proportion in the general tax. Then, for maintenance, every individual pays for the water which he uses. That can only be accomplished fairly by measuring, as accurately as possible, the water which he uses, costing that community to furnish so much per gallon. After you have provided for the expense of the establishment of the plant, dividing it among the individuals in that community, you have then eliminated from the question much of the difficulty.

In Massachusetts we are allowed to tax $12 on a thousand

* Ex-Mayor, Quincy, Mass.

for the current expenses of a community. We are allowed in addition to tax for the municipal debt, water debt, sewer debt, and everything of that sort. We charge that amount into our annual tax levy. Now, the individuals pay, in addition to that, for the maintenance of the water plant each year. If you establish meters and one man uses 10 000 gallons and another 1 000 gallons, one man pays at a fixed rate the cost of furnishing him with 10 000 gallons and the other man pays the cost of furnishing him with 1 000 gallons. The establishment of the plant has already been provided for, and has been eliminated from the account.

I do not believe in a flat rate. I do believe in assessing to each individual the cost per gallon of the water which he uses, and under those circumstances he cannot complain. The actual experience is this: We assess a fixed rate for water, which is guessed at, one man paying, say, $5 for so many fixtures, another man, without any knowledge of what he uses, pays another sum, and the result is an accumulation in excess of the expenses of the water department, which the legislative body will proceed to appropriate for other expenses of the municipality. The result is that in every community there is transfer from the receipts of water, amounts varying in different communities, but exceeding, to a large extent, in a great many communities, the amount which the statute allows them to tax to the city. I believe the only proper course is to put into the general levy the cost of construction, apportioned upon all the valuation, and then charge the individuals for the water which they use. Adopting that principle, you have simplified the question, you have made it fair, just, and equitable to every community, large and small. Adopting this policy may result in a reduction of revenue, but it will also result in a reduction of expenses; any expense will be divided as the *actual* cost and not an amount which is guessed at, which will yield an excess of revenue over cost, which may be at the disposal of the legislative body.

I believe it is the business of the water department to stand firmly to this principle: That the water should be furnished to the citizens at its cost, and that no profits should result from the administration of the water department which can be appropriated or applied to any other purpose.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, March 9, 1904.

President Brooks in the chair.

The following members and guests were present: —

Members.

S. A. Agnew, F. E. Appleton, C. H. Baldwin, L. M. Bancroft, J. E. Beals, George Bowers, E. C. Brooks, Fred Brooks, C. F. Chandler, J. C. Chase, F. C. Coffin, M. F. Collins, G. E. Crowell, A. W. Dean, L. N. Farnum, August Fels, B. R. Felton, C. R. Felton, J. H. Flynn, F. F. Forbes, A. D. Fuller, W. P. Gerhard, J. C. Gilbert, D. H. Gilderson, A. S. Glover, F. W. Gow, R. A. Hale, J. O. Hall, J. C. Hammond, Jr., T. G. Hazard, Jr., F. W. Hodgdon, H. G. Holden, J. L. Howard, Willard Kent, C. F. Knowlton, E. S. Larned, G. A. King, A. E. Martin, W. E. Maybury, F. E. Merrill, A. G. Pease, H. E. Perry, Dwight Porter, W. W. Robertson, C. M. Saville, S. P. Senior, C. W. Sherman, A. T. Safford, G. A. Stacy, G. T. Staples, F. P. Stearns, J. T. Stevens, W. F. Sullivan, C. N. Taylor, R. J. Thomas, W. H. Thomas, J. L. Tighe, W. H. Vaughn, C. K. Walker, G. E. Winslow, E. Worthington. — 61.

Honorary Member.

F. W. Shepperd. — 1.

Associates.

Builders Iron Foundry, by F. N. Connet; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; Hersey Mfg. Co., by Albert S. Glover, James A. Tilden, W. A. Hersey; Henry F. Jenks; Kennedy Valve Co., by M. J. Brosman; Lead Lined Iron Pipe Co., by T. E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by W. L. Dickel; National Lead Co., by G. L. Whittemore; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by W. H. Van Winkle and H. H. Kinsey; Norwood Engineering Co., by H. N. Hosford; Perrin, Seamans & Co., by James C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; A. P. Smith Mfg. Co., by D. F. O'Brien; Sumner & Goodwin Co., by H. A. Gorham; Sweet & Doyle, by H. L. DeWolfe; Thomson Meter Co., by S. D. Higley; The William Tod Co., by Irving H. Reynolds, Fred C. Gifford. — 25.

GUESTS.

Charles E. Harris, Superintendent Water Co., Rockville, Conn.; W. O. Mudge, Water Registrar, Lynn, Mass.; F. L. Weaver and R. J. Crowley, Members Water Board, Lowell, Mass.; J. F. Gleason, Quincy, Mass.; Alex MacPhail, Hingham, Mass.; Morris F. Whiton, Treasurer Water Co., Hingham, Mass.; John J. Moore, Hingham, Mass.; E. D. George and Frank Pease, Merrimac, Mass.; George E. Waite, Providence, R. I.; Mr. Dickens, Newburyport, Mass. — 12.

(Names counted twice. — 2.)

The following applicants, being recommended by the Executive Committee, were elected to membership: —

Elisha F. Haywood, Water Commissioner, Woburn, Mass.; Redmond E. Walsh, Water Registrar, Woburn, Mass.; Timothy V. Sullivan, General Foreman Meter Service, Boston Water Department, 1413 Washington Street, Boston, Mass.; Oren E. Parks, City Engineer, Westfield, Mass.; J. Emile Vanier, Chief Engineer cities of St. Henry and St. Cunegonde, also towns of Maisonneuve, St. Louis, and Valleyfield; address: 107 St. James Street, Montreal, Canada.

Mr. Charles K. Walker showed photographs of a boiler used by him for thawing frozen ground, hydrants, pipes, etc.

Mr. Charles H. Eglee, Hydraulic Engineer, of Boston, addressed the Association on the subject of "Experiences."

A topical discussion was opened by Mr. Freeman C. Coffin, C.E., of Boston, on "Rates for Metered Water," which was continued by Messrs. H. V. Macksey, Caleb M. Saville, F. F. Forbes, C. R. Felton, Frank E. Merrill, Frank L. Fuller, Andrew D. Fuller, William Paul Gerhard, John C. Chase, Julius C. Gilbert, and John O. Hall.

Mr. Frank A. McInnes, of Boston, gave an account of his experience during the past winter in thawing water pipes by electricity.

A paper prepared by Mr. Edward H. Cowan, Superintendent of Water Works, Marion, Ohio, on "The Detection and Prevention of Water Waste at Marion, Ohio," was read by Mr. Charles W. Sherman.

Adjourned.

EXECUTIVE COMMITTEE.

MARCH 9, 1904.

Present: President E. C. Brooks and Messrs. Bancroft, Beals, Hammond, Holden, W. Kent, Merrill, Sherman, and Thomas.

Five applications for membership were received and approved.

WILLARD KENT, *Secretary.*

OBITUARY.

JOHN C. BROATCH, Superintendent of Water Works at Middletown, Conn., died on April 2, 1904.

He was born in Middletown on March 14, 1843. He served throughout the Civil War in the Second and Fourteenth Connecticut regiments, and rose to the rank of major, with the brevet rank of colonel.

On February 4, 1871, Major Broatch was chosen Secretary of the Board of Water Commissioners and Superintendent of Water Works at Middletown, and held this position continuously until his death, with the exception of a single year. He also served in the state legislature in 1887 and 1888.

Mr. Broatch was elected a member of the New England Water Works Association on April 21, 1885.

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